Section 9

Alaska Sablefish Assessment for 2002

by

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9.1 Executive Summary

9.1.1 Summary of major changes

Relative to last year's assessment, we made the following substantive changes in the current assessment.

Input data: Relative abundance and length data from the 2001 longline survey, relative abundance and length data from the 2000 longline fishery, and age data from the 2000 longline survey and longline fishery were added to the assessment model. Ages from the 1985 longline survey recently were read and were added to the assessment model. With this addition, age data from at least every other survey year since 1981 now are incorporated into the assessment model. Length sample sizes from the trawl fishery often are too small to be used in the assessment. Sample size improved for 1999 through efforts of the Observer Program, but dropped again in 2000.

Assessment results: Sablefish abundance increased during the mid-1960's due to strong year classes from the late 1950's and 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 56,988 mt in 1972. The population recovered due to exceptional year classes from the late 1970's; spawning abundance peaked again in 1987. The population then decreased because these exceptional year classes are dying off.

The survey abundance index increased 16% in numbers and 13% in weight from 2000 to 2001. These increases follow decreases from 1999 to 2000 in the survey abundance index of 10% in numbers and 8% in weight and in the fishery abundance index of 5% in weight, so that relative abundance in 2001 is slightly higher than in 1999. Fishery abundance data for 2001 were not analyzed because the fishery remains open. Exploitable and spawning biomass are projected to increase 4 and 2%, respectively, from 2001 to 2002. **Alaska sablefish abundance now appears to be low and slowly increasing.** The slow increase confirms the projection from last year's assessment that abundance will increase slowly due to the above average 1995 and 1997 year classes; the size of the increase depends on the actual strength of the above-average 1997 year class and another year class that likely is above average, 1998. Spawning biomass is projected to increase to 35% of unfished spawning biomass ($B_{35\%}$) in 2002, having been as low as 33% of unfished spawning biomass during 1998 to 2000.

ABC recommendation and decision analysis: Our approach for recommending ABC has been to consider current abundance and trend. Current abundance is low and slowly increasing. We completed a decision analysis to determine what catch levels likely will result in stable or increasing spawning biomass. The decision analysis indicates that a yield of 17,300 mt likely will maintain spawning biomass. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is much higher, 21,300 mt. In contrast to a yield of 17,300 mt, the $F_{40\%}$ yield has a high probability (>0.99, decision analysis) of decreasing 2006 abundance below 2002 abundance and a substantial probability (0.18) of decreasing 2006 abundance below 90% of 2002 abundance. We recommend against the $F_{40\%}$ yield because this yield is likely to decrease spawning biomass. **We recommend a 2002 ABC of 17,300 mt for the combined stock**, a yield likely to maintain spawning biomass, and a yield slightly higher than the 2001 ABC of 16,900 mt (2% increase).

Regional ABC recommendation:

In December 1999, the Council approved an allocation of the 2000 ABC based on survey and fishery data. We used the same algorithm to allocate the 2002 ABC. A 5-year exponential weighting of the survey and fishery abundance indices in weight (relative population weight or RPW) by region and was used to apportion the combined ABC to regions, resulting in the following apportionments: Bering Sea 1,930 mt, Aleutian Islands 2,550 mt and Gulf of Alaska 12,820 mt, which is further apportioned Western 2,240 mt, Central 5,430 mt, West Yakutat 1,770 mt, and East Yakutat / Southeast 3,380 mt. The ABCs increase for the western areas (Bering, Aleutians, Western Gulf of Alaska, remain the same for the central area, and decrease for the eastern Gulf of Alaska. Abundance has steadily decreased in the eastern Gulf of Alaska during the 1990s, as well as the central Gulf of Alaska, though more slowly and variable. This abundance decrease and when it may reverse are discussed in section 9.4.5.

9.1.2 Response to Council, SSC, and Plan Team comments

At their fall 2000 meeting, the Plan Teams noted that fishery catch rate indices should be closely evaluated for bias potential and requested that the authors examine the logbook vs. observer reports for fishery catch rates in the next assessment. At their December 2000 meeting, the SSC supported inclusion of the longline (fishery) CPUE in both the assessment and area apportionments and encouraged continued investigation into inclusion of this data. We examined the fishery catch rate data for biases (section 9.4.2). We compared the logbook-based and observer-based catch rates (section 9.4.2). We examined the effect of excluding fishery catch rates in the assessment model (section 9.7.1).

At their December 2000 meeting, the SSC encouraged continued development of the decision theoretic approach as an alternative means of examining optimum harvest rates. We completed a second decision analysis examining the probability that spawning biomass will decrease below 35% of the unfished level (section 9.8.5).

9.1.3 Sablefish longline survey - fishery interactions, 1995-2001

Sablefish longline survey - fishery interactions for 1995-2001 are described in appendix C.

9.2 Introduction

Distribution: Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea (Wolotira et al 1993). Adult sablefish occur along the continental slope, shelf gulleys, and in deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Kreiger 1997).

Stock structure and management units: Sablefish appear to form two populations, a northern or Alaska population and a southern or west coast population, based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). The Alaska population inhabits Alaska and northern British Columbia waters and the southern population inhabits southern British Columbia and Washington, Oregon and California waters, with mixing of the two populations occurring off southwest Vancouver Island and northwest Washington.

Alaska sablefish are highly migratory for at least part of their life and substantial movement between the Bering Sea-Aleutian Islands and the Gulf of Alaska has been documented (Heifitz and Fujioka, 1991; Maloney and Heifitz, 1997; Kimura et al. 1998). Thus sablefish in Alaska waters are assessed as a single population. However, sablefish are managed by discrete regions to distribute exploitation throughout their wide geographical range. There are four management areas in the Gulf of Alaska: Western, Central, West Yakutat, and East Yakutat/Southeast Outside (SEO) and two management areas in the Bering Sea/Aleutian Islands (BSAI): the eastern Bering Sea (EBS) and the Aleutian Islands region.

Early life history: Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 180 miles (Wing 1997). Average spawning date based on otolith analysis is March 30 (Sigler et al. 2001). During surveys of the outer continental shelf, most young-of-the-year sablefish are caught in the central and eastern Gulf of Alaska (Sigler et al. 2001). Near the end of the first summer, pelagic juveniles less than 20 cm drift inshore and spend the winter and following summer in inshore waters, reaching 30-40 cm by the end of their second summer (Rutecki and Varosi 1997). After their second summer, they begin moving offshore, typically reaching their adult habitat, the upper continental slope at 4 to 5 years.

Age and Size of Recruitment: Juvenile sablefish rear in nearshore and continental shelf waters, moving to the upper continental slope as adults. Fish first appear on the upper continental slope, where the longline survey and longline fishery primarily occur, at age 2 and length about 50-53 cm fork length, although only 10% are estimated to reach the slope at that young age. Fish are susceptible to trawl gear at an earlier age than to longline gear because trawl fisheries usually occur on the continental shelf and shelf break inhabited by younger fish.

Growth and maturity: Sablefish grow rapidly in early life, growing 1.2 mm d^{-1} during their first spring and summer (Sigler et al. 2001). Within 100 days after first increment formation, they average 120 mm. They reach average maximum lengths and weights of 69 cm and 3.4 kg for males and 83 cm and 6.2 kg for females. Fifty percent of females mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.5 years for females and about 5 years for males (Table 9.1). The length (L) -age (t) functions are $L = 68.8\,(1- e^{-0.167\,(t\,-\,-5.8)})$ for males and $L = 82.8\,(1- e^{-0.120\,(t\,-\,-6.3)})$ for females (Sigler et al. 1997). The weight (W) - length function is $W = 0.0000474\,L^{3.19}$ (Sasaki 1985, all areas). The maturity (M) - length function is $M = 1 / (1 + e^{-0.40\,(L\,-\,57)})$ for males and $M = 1 / (1 + e^{-0.40\,(L\,-\,65)})$ for females. Maturity at age was computed using logistic equations fit to the length/maturity relationships shown in Sasaki (1985, Figure 23, Gulf of Alaska). A value of 0.4 is used for the slope parameter for maturity at length (cm) of 50 percent maturity.

Maximum age and natural mortality: Sablefish are long-lived; ages over 40 years are regularly recorded (Kimura et al. 1993). Reported maximum age for Alaska is 94 years (Kimura et al. 1998); the previous reported maximum was 62 (Sigler et al 1997). Canadian researchers report age determinations up to 55 years (McFarlane and Beamish, 1983). A natural mortality rate of M=0.10 has been assumed for previous sablefish assessments, compared to M=0.112 assumed by Funk and Bracken (1984). Johnson and Quinn (1988) used values of 0.10 and 0.20 in a catch-at-age analysis and found that estimated abundance trends agreed better with survey results when M=0.10 was used. In the current assessment, natural mortality is estimated rather than assumed to equal 0.10 as in assessments before 1999. The estimated value is about 0.10.

Prey and predators: Young-of-the-year sablefish diet was mostly euphausiids (Sigler et al. 2001). For juvenile and adult sablefish, larger-sized sablefish (> 60 cm FL) consumed more fish than smaller-sized sablefish, which consumed more euphausiids, shrimp, and cephalopods (Yang and Nelson 2000). Juvenile and adult sablefish are opportunistic feeders. Fish constituted 3/4 of stomach content weight, with the remainder invertebrates, in the Gulf of Alaska sablefish diet study (Yang and Nelson 2000). Pollock were the most important fish; eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish also were found. Squid were the most important invertebrate and euphasiids and jellyfish both also were found. Fish made up 76 percent of the diet in feeding studies conducted off Oregon and California (Laidig et al 1997). Euphausiids dominated the diet off the southwest coast of Vancouver Island; herring and other fish were increasingly important with sablefish size (Tanasichuk 1997).

Adult coho and chinook salmon feed on sablefish; they prey on young-of-the-year sablefish, which were the fourth most commonly reported species from the salmon troll logbook program from 1977 to 1984 (Wing 1985). Only one other fish species was reported as preying on juvenile or adult sablefish in a food habit study of fishes of the Gulf of Alaska, Pacific halibut, and sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999).

9.3 Fishery

9.3.1 Description of the directed fishery

Early U.S. fishery, 1976 and earlier

Sablefish have been exploited since the end of the 19th century by U.S. and Canadian fishermen. The North American fishery on sablefish developed as a secondary activity of the halibut fishery of the United States and Canada. Initial fishing grounds were off Washington and British Columbia and from there spread to Oregon, California, and Alaska during the 1920's. Since then, and up to 1957, the sablefish fishery was exclusively a U.S. and Canadian fishery, ranging from off northern California northward to Kodiak Island in the Gulf of Alaska; catches were relatively small, averaging 1,666 mt from 1930 to 1957, and generally limited to areas near fishing ports (Low et al 1976).

Foreign fisheries, 1958 to 1987

Japanese longliners began operations in the eastern Bering Sea in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 mt in 1962 (Table 9.2, Figure 9.1). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the Aleutian Islands region and the Gulf of Alaska. In the Gulf of Alaska, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 mt overall in 1972. Catches in the Aleutian Islands region have historically remained at low levels with Japan harvesting the largest portion of the sablefish catch. Most sablefish harvests were taken from the eastern Being Sea until 1968, and then from the Gulf of Alaska until 1977. Heavy fishing by foreign vessels during the 1970's led to a substantial population decline and fishery regulations in Alaska which sharply reduced catches. Catch in the late 1970's was restricted to about one-fifth of the peak catch in 1972.

Japanese longliners had a directed fishery for sablefish. Sasaki (1985) described the gear used in the directed Japanese longline fishery. He found only minor differences in the structure of fishing gear and the fishing technique used by Japanese commercial longline vessels. There were small differences in the length of hachis (Japanese term for a longline skate) and in the number of hooks among vessels, but hook spacing remained about 1.6 m. The use of squid as bait by vessels also remained unchanged, except some limited number of vessels used Pacific saury as bait when squid was expensive. The standard number of hachis fished per day was 376 (Sasaki 1978) and the number of hooks per hachi was 43 until 1979, when the number was reduced to 40 (T. Sasaki, Japan Fisheries Agency, 4 January 1999).

Japanese trawlers also caught sablefish through directed effort toward sablefish, but mostly as bycatch in fisheries targeting other species. Sasaki (1973) reported two trawl fisheries catching sablefish in the Bering Sea through 1972, the North Pacific trawl fishery which caught sablefish as bycatch to the directed pollock fishery and the landbased dragnet fishery that sometimes targeted sablefish. The latter fishery mainly targeted rockfishes, Greenland turbot, and Pacific cod, and only a few vessels targeted sablefish (Sasaki 1985). The landbased fishery caught more sablefish, averaging 7,300 mt from 1964 to 1972, compared to the North Pacific trawl fishery, which averaged 4,600 mt. In the Gulf of Alaska, Sasaki (1973) reported that sablefish were caught as bycatch to the directed Pacific Ocean perch fishery until 1972, but some vessels started targeting sablefish in 1972. Most net-caught sablefish were caught by stern trawls, but significant amounts also were caught by side trawls and Danish seines the first few years of the Japanese trawl fishery.

Other foreign nations besides Japan also have caught sablefish. Substantial U.S.S.R. catches were reported from 1967-73 in the Bering Sea (McDevitt 1986). Substantial R.O.K. catches were reported from 1974-1983 scattered through Alaska. Other countries reporting minor sablefish catches were Republic of Poland, Taiwan, Mexico, Bulgaria, Federal Republic of Germany, and Portugal. The U.S.S.R. gear was factory-type stern trawl and the R.O.K. gear was longlines and traps (Low et al 1976).

Recent U.S. fishery, 1977 to present

The U.S. longline fishery began expanding in 1982 in the Gulf of Alaska and in 1988, harvested all sablefish taken in Alaska except minor joint venture catches. Following domestication of the fishery, the previously year-round season in the Gulf of Alaska began to shorten in 1984. By the late 1980's, the average season length decreased to one to two months. In some areas, this open-access fishery was as short as 10 days, warranting the label “derby” fishery.

Year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Season length (months)	12	7.6	3.0	1.5	1.2	1.8	1.5	1.3	0.9	0.7	0.5	0.3	8

Season length continued to decrease until Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels in 1995 along with an 8-month season. The season runs from March 15-November 15, concurrent with the halibut IFQ fishery.

The expansion of the U.S. fishery was helped by exceptional recruitment during the late 1970's. This exceptional recruitment fueled an increase in abundance for the population which had been heavily fished during the 1970's. Increased abundance led to relaxation of fishing quotas and catches peaked again in 1988 at about 70% of the 1972 peak. Abundance has since fallen as the exceptional late 1970's year classes have died off. Catches also have fallen and in 2000, were about 42% of the 1988 peak.

IFQ management has increased fishery catch rate and decreased harvest of immature fish (Sigler and Lunsford 2001). Catching efficiency increased 1.8 times with the change from an open-access to an IFQ fishery. The improved catching efficiency of the IFQ fishery reduced variable costs to catch the quota from eight to five percent of landed value, a savings averaging US$3.1 million annually. Decreased harvest of immature fish improved the chance that individual fish will reproduce at least once. Spawning potential of sablefish, expressed as spawning biomass per recruit, increased nine percent for the IFQ fishery.

The directed fishery primarily is a hook-and-line fishery. Sablefish also are caught as bycatch during directed trawl fisheries for other species groups such as rockfish and deepwater flatfish. Five state fisheries also land sablefish outside the IFQ program; the major fisheries in the Prince William Sound, Chatham Strait, and Clarence Strait and the minor fisheries in the northern Gulf of Alaska and Aleutian Islands. For Federal and State sablefish fisheries combined, the number of longline vessels targeting sablefish (Greig et al. 1998, Hiatt and Terry 2000) was:

Year	1993	1994	1995	1996	1997	1998	1999
Vessels	871	1,078	613	578	504	450	444

The number of hooks deployed in the Federal fishery alone were:

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Hooks (millions)	96.9	78.0	84.9	86.7	81.5	50.1	45.1	34.4	35.0	33.2	43.4

Longline gear in Alaska is fished on-bottom. In the 1996 directed fishery for sablefish, average set length was 9 km and average hook spacing was 1.2 m. The gear is baited by hand or by machine, with smaller boats generally baiting by hand and larger boats generally baiting by machine. Circle hooks usually are used, except for modified J-hooks on some boats with machine baiters. The gear usually is deployed from the vessel stern with the vessel traveling at 5-7 knots. Some vessels attach weights to the longline, especially on rough or steep bottom, so that the longline stays in place and lays on-bottom.

9.3.2 Catch

Annual catches in Alaska averaged about 1,700 mt from 1930 to 1957 and exploitation rates remained low until Japanese vessels began fishing for sablefish in the Bering Sea in 1959 and the Gulf of Alaska in 1963. Catches rapidly escalated during the mid-1960's. Annual catches in Alaska reached peaks in 1962, 1972, and 1988 (Table 9.2). The 1972 catch was the all-time high, at 53,080 mt, and the 1962 and 1988 catches were 50% and 72% of the 1972 catch. Evidence of declining stock abundance led to significant fishery restrictions from 1978 to 1985, and total catches were reduced substantially. Catches averaged about 12,200 mt during this time. Exceptional recruitment fueled increased abundance and increased catches during the late 1980's. The domestic fishery also expanded during the 1980's, harvesting 100% of the catch in the Gulf of Alaska by 1985 and in the Bering Sea and Aleutians by 1988. Catches have declined during the 1990's. Catches peaked at 38,406 mt in 1988 and have fallen to about 16,000 mt currently due to reduced quotas.

9.3.3 Bycatch and discards

The percent of sablefish catch discarded during 1995 to 2000 averaged 2.8% in the directed Alaska-wide sablefish longline fishery, 31.0% in the Bering Sea/Aleutian Islands Greenland turbot longline fishery, and 41.4% in the Bering Sea/Aleutian Islands Pacific cod longline fishery. Sablefish discard averaged 17.4% in Alaska-wide rockfish trawl fisheries and 42.1% in flatfish trawl fisheries (Table 9.3). The average discard from 1994 to 1997 was 3.7% for all longline fisheries and 30% for all trawl fisheries.

9.3.4 Previous management actions

Quota allocation: Amendment 14 to the Gulf of Alaska Fishery Management Plan, allocated the sablefish quota by gear type: 80% to hook-and-line gear and 20% to trawl in the Western and Central Gulf of Alaska and 95% to hook-and-line gear and 5% to trawl in the Eastern Gulf of Alaska, effective 1985. Amendment 13 to the Bering Sea/Aleutian Islands Fishery Management Plan, allocated the sablefish quota by gear type, 50% to fixed gear and 50% to trawl in the eastern Bering Sea, and 75% to fixed gear and 25% to trawl gear in the Aleutians, effective 1990.

IFQ management: Amendment 20 to the Gulf of Alaska Fishery Management Plan and 15 to the Bering Sea/Aleutian Islands Fishery Management Plan established IFQ management for sablefish beginning in 1995.

These amendments also allocated 20% of the fixed gear allocation of sablefish to a CDQ reserve for the Bering Sea and Aleutian Islands.

Maximum retainable bycatch: Maximum retainable bycatch percentages for sablefish were revised in the Gulf of Alaska by a regulatory amendment, effective 4/10/97. The percentage depends on the basis species: pollock 1%, Pacific cod 1%, deep flatfish 7%, rex sole 7%, flathead sole 7%, shallow flatfish 1%, arrowtooth flounder 0%, Pacific ocean perch 7%, shortraker and rougheye rockfish 7%, other rockfish 7%, northern rockfish 7%, pelagic rockfish 7%, demersal shelf rockfish in the Southeast Outside district 7%, thornyhead 7%, Atka mackerel 1%, other species 1%, and aggregated amount of non-groundfish species 1%.

Allowable gear:

Amendment 14 to the Gulf of Alaska Fishery Management Plan banned the use of pots for fishing for sablefish in the Gulf of Alaska, effective 18 November 1985, starting in the Eastern area in 1986, in the Central area in 1987, and in the Western area in 1989. An earlier regulatory amendment was approved in 1985 for 3 months (3/27-6/25/1985) until Amendment 14 was effective. A later regulatory amendment in 1992 prohibited longline pot gear in the Bering Sea (57 FR 37906). The prohibition on sablefish longline pot gear use was removed for the Bering Sea, except from June 1 to 30 to prevent gear conflicts with trawlers during that month, effective 9/12/96. Sablefish longline pot gear are allowed in the Aleutian Islands.

Management areas: Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish, effective 1980.

9.4 Data

Source	Data	Dates
Fisheries	Catch	1960-2000
Japanese longline fishery	Effort	1964-1981
	Length	1963-1980
Japanese trawl fishery	Length	1964-1971
U.S. longline fishery	Effort, length, discards	1990-2000
U.S. trawl fisheries	Length	1990,1991,1999
	Discards	1990-2000
Japan-U.S. cooperative longline survey	Catch, effort, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	Catch, effort, length	1990-2001
	Age	1996-2000

9.4.1 Fishery

Catch, effort, and length data are collected from sablefish fisheries. The catch data covers several decades. Length and effort data were collected from the Japanese and U.S. longline fisheries (Table 9.4). Length data were collected from the Japanese and U.S. trawl fisheries. The Japanese data were collected by fishermen trained by Japanese scientists (L-L. Low, Alaska Fisheries Science Center, 25 August 1999). The U.S. fishery data were collected by at-sea and plant observers. No age data were systematically collected from the fisheries until 1999 because of the difficulty of obtaining representative samples from the fishery and because a limited number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A.

The catches used in this assessment (Table 9.2) include catches from minor state waters fisheries in the northern Gulf of Alaska and in the Aleutian Islands region. These minor state fisheries were established by the State of Alaska in 1995, the same time as the Federal Government established the IFQ fishery. The state established these fisheries primarily to provide open-access fisheries to fishermen who could not participate in the IFQ fishery. Fish caught in these state waters are reported using the area code of the adjacent Federal waters in Alaska Regional Office catch reporting system (G. Tromble, 7/12/1999), the source of the catch data used in this assessment. Catches from these state waters averaged 180 mt from 1995-1998 (ADFG), about 1% of the average total catch of 16,890 mt. Most of the catch (80%) is from the Aleutian Islands region. The effect of including these state waters catches in the assessment is to overestimate biomass by about 1%, a negligible error considering statistical variation in other data used in this assessment.

Some catches probably were not reported during the late 1980's (Kinoshita et al 1995). Unreported catches could account for the Japan-U.S. cooperative longline survey index's sharp drop from 1989-90 (Figures 9.2 and 9.3, Table 9.5). We tried to estimate the amount of unreported catches by comparing reported catch to another measure of sablefish catch, sablefish imports to Japan, the primary buyer of sablefish. However the trends of reported catch and imports were similar, so we decided to change our approach for catch reporting in the 1999 assessment. We assumed that non-reporting is due to at-sea discards and apply discard estimates from 1994 to 1997 to inflate U.S. reported catches before 1994 (2.9% for hook-and-line and 26.6% for trawl).

One problem with the fishery data has been low length sample sizes for the trawl fishery. From 1992 to 1998, few lengths were collected each year and the resultant length frequencies were ragged and could not be used in the assessment model. The problem was that sablefish often are caught with other species like rockfish and deepwater flatfish, but are not the predominant species. The observer sampling protocol called for sampling the predominant species, so sablefish were poorly sampled. We communicated this problem to the observer program and together worked out revised sampling protocols. The revision greatly improved the sample size, so that the 1999 length data for the trawl fishery can be used for the assessment. Unfortunately the sample size decreased in 2000, falling from 1,268 lengths to 472 lengths, and the resultant length composition can not be used for the assessment.

9.4.2 Longline fishery catch rate

Steady declines in longline survey catch rates of sablefish have led to reduced fishery quotas in recent years. Some fishermen are concerned that their catch rates have remained strong in some areas despite the decline in longline survey catch rates. Extensive fishery information is available from the observer program and logbooks. We computed fishery catch rates based on observer and logbook data and compared these fishery catch rates to longline survey data. We checked and did not find any substantial changes in fishery effort by season or area. Such changes may cause fishery catch rates to be unrepresentative of abundance. For example, fishermen sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). Overfishing of northern (Newfoundland) cod likely was made worse by incorrect interpretation of fishery catch rates: assessment scientists did not realize that the area occupied by the stock was diminishing while fishery catch rate remained level (Rose and Kulka 1999).

Fishery data is recorded by observers and in voluntary and required logbooks. Vessels over 60 feet carry an observer 30% of the time if less than 125 feet and 100% of the time if over 125 feet. Logbooks are required for vessels over 60 feet. Some captains of vessels less than 60 feet participate in a voluntary logbook program initiated in 1997. Sample sizes are 18,881 sablefish target longline sets from 1990 to 2000 for observer data, 6,832 for required logbooks from 1999 to 2000, and 538 for voluntary logbooks from 1997 to 2000 (Table 9.6).

Only sets targeting sablefish are included, defined as a set where sablefish were at least 50% of the catch by weight. The logbook reported weights usually are approximate because vessel captains typically estimate and record catch for each set in the logbook while at sea and without an accurate scale measurement. An accurate weight for the entire trip is measured at landing and recorded as the IFQ landing report. We adjusted the captain's estimate of catch per set using the ratio of IFQ landing report and logbook reported weight.

Hook spacing was standardized to a 39 inch (1m) spacing following the method used for standardizing halibut catch rates (Skud and Hamley, 1978; Sigler and Lunsford, 2001). 39 and 42 inch spacings were the most common spacings in the directed sablefish fishery (64% of all sets from 1990 to 1999) . Each set's catch rate was calculated by dividing the catch in weight by the standardized number of hooks, then used to compute average catch rates by vessel and NPFMC region. The observer and voluntary logbook data were combined when computing average catch rates. The required logbook data are available for the first time this year, so were treated as a separate data set.

The Central Gulf region had the most sets observed (Table 9.6). Fewer sets were observed for the Bering Sea and for 1997 and 1998, the Aleutians. The voluntary logbook data is an important supplement to the observer data, especially in the West Yakutat and East Yakutat/Southeast areas. More sets were reported for required logbook data than observer data, especially in the Bering Sea and East Yakutat/Southeast. In 2000, 14% of catch was observed and 31% was reported in required logbooks. The latter value is too low; these vessels caught 48% of total catch. We are checking our logbook database for the cause of this discrepancy.

Fishery catch rates recorded by observers were highest in West Yakutat, and East Yakutat/Southeast, closely followed by the Central Gulf, and substantially more than Western Gulf, Bering Sea, and Aleutian Islands (Figure 9.4). Catch rates generally declined from 1990 to 1994 in the Bering Sea, Aleutian Islands and Western Gulf and generally were similar in Central Gulf, West Yakutat and East Yakutat/Southeast. Catch rates increased in all areas between 1994 and 1995 likely due to the implementation of the Individual Fishing Quota (IFQ) system. Catch rates generally declined from 1995 to 2000 in the eastern Bering Sea and generally were similar in the Aleutian Islands, Western Gulf, Central Gulf, and East Yakutat/Southeast. The remaining area, West Yakutat, increased.

Survey catch rates generally are higher than fishery catch rates except in the Bering Sea and Aleutians and since 1995 in West Yakutat and East Yakutat/Southeast (Figure 9.4). The fishery and survey catch rate trends from 1995 to 2000 are similar in all Gulf of Alaska areas except West Yakutat, where survey catch rate declined steadily since 1996, but fishery catch rates have increased since 1997.

Required logbook fishery catch rates are similar to observer fishery catch rates in the Aleutian Islands, Western Gulf, and East Yakutat/Southeast and especially Central Gulf (Figure 9.4), the area with the highest sample size (Table 9.6). Catch rates are probably significantly different for the Bering Sea in 1999 and West

Yakutat in 2000, since the confidence intervals do not include the means (Figure 9.5). For the Bering Sea in 1999, observer sample size was lower than logbook sample size. Targeting of Greenland turbot, which co-occur with sablefish in the Bering Sea, may also add variability to fishery catch rates. For West Yakutat in 1999, the catch rates are similar, but in 2000 the observer catch rates increase and the logbook catch rates decrease. Notably the logbook catch rates are very similar to the trend seen in the survey catch rates. Collection of logbook data will continue in the future, increasing the number of data points and allowing more detailed comparisons with the logbook fishery catch rates.

9.4.3 Longline surveys

Catch, effort, age, length, weight, and maturity data are collected during sablefish longline surveys. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000). Japan and the United States conducted a cooperative longline survey for sablefish in the Gulf of Alaska annually from 1978 to 1994, adding the Aleutians Islands region in 1980 and the eastern Bering Sea in 1982 (Sasaki 1985, Sigler and Fujioka 1988). Since 1987, the Alaska Fisheries Science Center has conducted annual longline surveys of the upper continental slope, referred to as domestic longline surveys, designed to continue the time series of the Japan-U.S. cooperative survey (Sigler and Zenger 1989). The domestic longline survey began annual sampling of the Gulf of Alaska in 1987, biennial sampling of the Aleutian Islands in 1996, and biennial sampling of the eastern Bering Sea in 1997 (Rutecki et al 1997). The domestic survey also samples major gullies of the Gulf of Alaska in addition to sampling the upper continental slope. The order in which areas are surveyed was changed in 1998 to reduce interactions between survey sampling and short, intense fisheries. Before 1998, the order was Aleutians and/or Bering Sea, Western Gulf, Central Gulf, Eastern Gulf. Starting in 1998, the Eastern area was surveyed before the Central area. Longline survey catches are tabled in appendix D.

Length data were collected for all survey years and sablefish otoliths were collected for most survey years. Only a subset of these otoliths were aged until 1996, when annual ageing of samples began. Otolith collections were length-stratified from 1979-94 and random thereafter.

Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 9.5). Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

Killer whale depredation of the survey's sablefish catches has been a problem in the Bering Sea since the beginning of the survey (Sasaki, 1987). The problem occurred mainly east of 170° W in the eastern Bering Sea and to a lesser extent in the northeast Aleutians between 170° W and 175° W. The 1983 (Sasaki 1984), 1986 and 1987 (T. Sasaki, Far Seas Fisheries Research Laboratory) and 1988 Bering Sea abundance indices likely were underestimated, although sablefish catches were lower at all stations in 1987 compared to 1986, regardless of whether killer whales were present. Killer whale depredation has been fairly consistent since 1988. An analysis is planned as time permits to exclude killer whale affected stations from abundance calculations with the cooperative longline survey data. Portions of the gear affected by killer whale depredation during domestic longline surveys already are excluded from the analysis of the survey data.

Sperm whale depredation may affect longline catches. Data on apparent sperm whale depredation has been recorded since the 1998 longline survey (Table 9.7). Apparent sperm whale depredation is defined as sperm whales are present and damaged sablefish are retrieved. Sperm whales also are present when fish are retrieved undamaged (about 45% of the time), in which case the sperm whales apparently feed off discard.

The number of stations with sperm whale depredation was four in 1998, twelve in 1999, five in 2000, and five in 2001. An average of eight damaged sablefish per station were retrieved. We tested whether sablefish catches were less at affected stations and found a significant difference. The standard residual for the relative population number (RPN) for each station compared to the mean RPN for the area was computed. Standard residuals were significantly less at the affected stations (Mann-Whitney test (a nonparametric rank test), one-sided test, $p = 0.035$). The median standard residual for stations with depredation was -0.147 compared to 0.106 for unaffected stations, implying sperm whales removed twenty-three percent of the sablefish at stations where depredation occurred. Unlike our analysis, an earlier study found no significant effect (Hill et al. 1999). The earlier study compared longline fishery catches between sets with sperm whales present and absent. The likely reason they could not find a significant effect was that their analysis included all sperm whale sightings, whether depredation occurred or not, thus tending to mask any effect.

The longline survey catch rates were not adjusted for sperm whale depredation because we don't know when significant depredation began. Current abundance is unbiased if depredation has consistently occurred over time. If significant depredation began recently, then current biomass is underestimated because the relationship between the survey index and biomass has changed. However if we adjust recent catch rates for sperm whale depredation when in fact it has happened all along, then current biomass will be overestimated. We do not plan to adjust longline survey catch rates for sperm whale depredation. We will continue to monitor sperm whale depredation of survey catches for changes in the level of depredation.

9.4.4 Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted approximately triennially since 1979 in the Bering Sea, 1980 in the Aleutians, and 1984 in the Gulf of Alaska. Trawl surveys of the Eastern Bering Sea shelf are conducted annually, but sablefish have never occurred on the shelf in large numbers except for juveniles of the 1977 year class which showed up in large numbers in 1978. The slope trawl surveys are not considered good indicators of the sablefish relative abundance over time because of differences in net types used each year, depths sampled, and high sampling variation and so are not used in the sablefish assessment. Trawl survey catches are tabled in appendix D.

9.4.5 Recruitment data

Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1 juveniles likely indicates a strong year class. Abundant age-1 juveniles were reported for the 1959 (J. Fujioka & H. Zenger, NMFS, approximate year), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, ADFG), and the 1998 year class near Kodiak Island (D. Jackson, ADFG).

Catch, effort, age, length, and diet data for young-of-the-year sablefish have been collected since 1995 during annual surface gillnet surveys of the Aleutian Islands, Bering Sea, and Gulf of Alaska. Catch rates of young-of-the-year sablefish imply that the 1995, 1997, and 1998 year classes may be above average within this 6-year period.

9.4.6 Relative abundance trends

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 9.5, Figures 9.2 and 9.3). The post-1970 decrease likely is due to heavy fishing. The 1985 peak likely is due to the exceptional late 1970's year classes. Since 1988, relative abundance has decreased substantially. Regionally, abundance decreased faster in the Eastern Bering Sea, Aleutian Islands, and western Gulf of Alaska and more slowly in the central and eastern Gulf of Alaska (Figure 9.6). These regional abundance changes likely are due to size-dependent migration. Small sablefish typically migrate westward, while large sablefish typically migrate eastward (Heifetz and Fujioka 1991). The recruitment of the strong late 1970s year classes accounted for the sharp increase in overall abundance during the early 1980s. During the late 1980s as sablefish moved eastward, abundance fell quickly in the western areas, fell slowly in the Central area, and remained stable in the Eastern area. The size-dependent migration and pattern of regional abundance changes indicate that the western areas are the outer edges of sablefish distribution and less favored habitat than the apparent center of sablefish abundance, the central and eastern Gulf of Alaska.

Above average year classes typically are first abundant in the western areas, another consequence of size-dependent migration. For example, an above average 1984 year class first became an important year class in western areas at age 5 (1998 plot), but not until age 9 (1993 plot) in the central and eastern areas (Figure 9.7). This pattern holds true for the above average year classes 1980-81, 1984, 1990, and 1995 which became abundant in the central area at ages 7-9 and in the eastern area at ages 7-10 (Table 9.8a). This pattern fails only for the 1977 year class, which became an important year class in the central and eastern areas at age 4 (1981 plot).

We can predict when the above 1995 and 1997 year classes will become abundant in the central and eastern Gulf of Alaska based on these patterns. We exclude the 1977 year class pattern from the prediction because these year classes would already be abundant in the central and eastern Gulf of Alaska if they followed the behavior of the 1977 year class. The 1995 year class is predicted to become abundant in the central Gulf of Alaska in 2002 to 2004 and in the eastern Gulf of Alaska in 2002 to 2005 (Table 9.8b). The 1997 year class is predicted to become abundant in the western Gulf of Alaska in 2001 to 2003, in the central Gulf of Alaska in 2004 to 2006 and in the eastern Gulf of Alaska in 2004 to 2007. Decreasing abundance may reverse in the central and eastern Gulf of Alaska once the 1995 and 1997 above average year classes become abundant in these areas.

9.5 Analytic approach

9.5.1 Model

Model structure

The analysis generally follows the approach described by Kimura (1990) for age-structured population analysis. This approach also was tested for sablefish by Sigler (1999). The analysis was completed using AD model builder software, a C++ based software for development and fitting of general nonlinear statistical models (Otter Research 1996). Details of the model structure are shown in Appendix B.

The sablefish population in Alaska is represented with an age-structured model. The age range for the model is 2 to 31, where 31 represents all ages 31 and greater. Abundance for years 1960 to 2001 are estimated.

Sablefish are difficult to age, especially those older than eight years (Kimura and Lyons 1991). To compensate, we use an ageing error matrix based on known-age otoliths (Heifetz et al. 1999). An age-length transition matrix also was used to translate predicted age frequencies into predicted length frequencies.

Selectivity is represented using a function and is separately estimated for longline survey, longline fishery, and trawl fishery. Selectivity for longline survey and longline fishery is restricted to be asymptotic.

Selectivity for trawl fishery is allowed to be dome-shaped. The age of 50% availability for longline fisheries is allowed to vary linearly with season length. Fishermen may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the pre-1995 "derby" fishery, when fishermen reportedly often fished in less productive depths due to crowding. In choosing their ground, they presumably target bigger, older fish.

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, and the U.S. longline fishery. Information is available to link these estimates of catchability. Kimura and Zenger (1997) analyzed the relationship between the cooperative and domestic longline surveys. We used their results to create a prior distribution which linked catchability estimates for the two surveys. Sasaki (1979) and Sigler and Lunsford (2001) conducted hook spacing experiments. The fishery and survey data differ in their hook spacing but otherwise are similar. We used the hook spacing data to create prior distributions which linked the catchability estimates for the surveys and fisheries.

A natural mortality rate of M=0.10 was assumed for assessments before 1999. Since then, natural mortality is estimated in the assessment model.

Some information used in the assessment model was estimated independently of the assessment model. For example, growth and maturity parameters were estimated separately and then incorporated into the assessment model as fixed values.

Standard set of population projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2001 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2002 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2001. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2002, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2002 recommended in the assessment to the *max* F_{ABC} for

2001. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1997-2001 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2002 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

Scenario 7: In 2002 and 2003, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014 under this scenario, then the stock is not approaching an overfished condition.)

Bayesian analysis

Previous sablefish assessments assumed that the value of natural mortality was known exactly. Since the 1999 assessment, we incorporated uncertainty in the value of natural mortality as well as survey catchability using the same approach as the Pacific cod assessments. Other population parameters are uncertain, but uncertainty in only these two parameters was examined because they are the most important parameters determining the value of abundance.

The likelihood surface was mapped over a grid of equally spaced M and q-values. The remaining population parameters were estimated with the population model given each M - q pair. The resulting likelihood values are an estimate of the likelihood surface given M and q. Each M - q pair was assumed to have equal prior probability, so the posterior probabilities were computed by normalizing the likelihoods (i.e. sum to 1.0). To ensure adequate coverage of the likelihood surface, we examined the density along the grid boundaries.

Decision analysis

Our approach for recommending ABC has been to consider current abundance and trend. Current abundance is low and slowly increasing. We wish to find a catch level that results in stable or increasing abundance. To do this we constructed a set of projection runs based on fixed catch levels. We ran 16 different scenarios using catches of 10, 11, ... 25 thousand metric tons. Each scenario was repeated 250 times, resampling from the estimated year classes from 1982-97. The probability of decreasing abundance (2006 abundance < 2002 abundance) was computed for several values of catch from the posterior probability of the Bayesian analysis. Five years was chosen for the projection time frame because projected abundance is only slightly influenced by the assumed value of future stock productivity compared to longer-term projections. Year classes earlier than 1982 were not included in the projections because the 1977-1981 year classes were stronger and may not recur in the next five years. These strong year classes were associated with a singular event, the regime shift, and we don't know when this event may recur.

9.6 Model evaluation

9.6.1 Data fits

The model fit the observed abundance indices, survey and fishery length data, and survey age data (Figures 9.2, 5.3, and 9.8 [the length fits are not shown for brevity]).

9.7 Results

9.7.1 Model

Annual estimated recruitment varies widely, with strong year classes estimated for 1960, 1964, 1967, 1974, 1977, 1980, 1981, 1984, 1988, 1990, 1994, 1995, and 1997 (Figure 9.9). Intervening year classes are relatively weak. Two recent strong year classes are the 1995 and 1997 year classes. The 1998 year class also may be strong, see section 9.4.5 for evidence, but appears relatively weak in the model estimates. Estimates of the strength of recent year classes strength are uncertain because these year classes have been observed only a few times and are only partially recruited. More reliable estimates of the strength of the 1998 year class will be available with 1-2 more years of survey data.

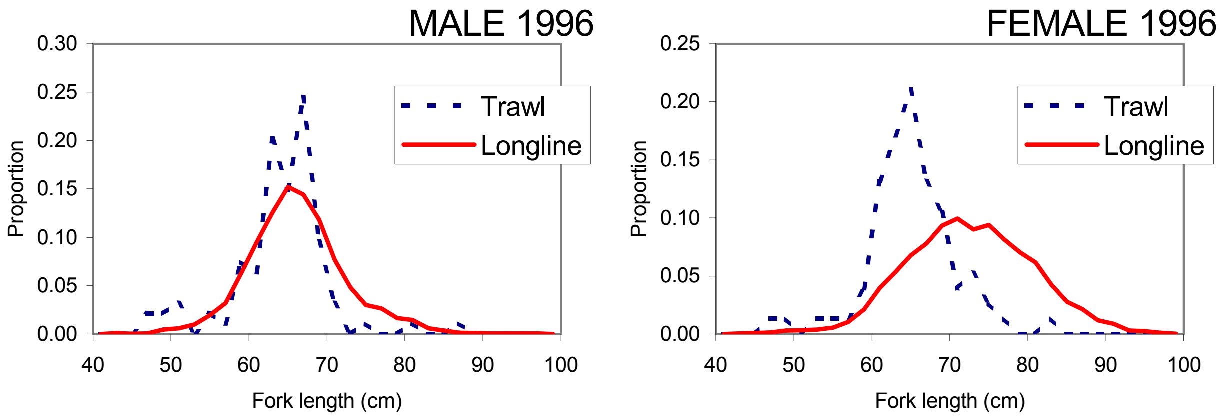
Sablefish abundance increased during the mid-1960's (Table 9.9, Figure 9.10) due to strong year classes from the late 1950's and 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 56,988 mt in 1972. The population recovered due to strong year classes from the late 1970's; spawning abundance peaked again in 1987. The population then decreased because these strong year classes are dying off.

Combined exploitable biomass for the Aleutian Islands, eastern Bering Sea, Gulf of Alaska increased 2.2% and spawning biomass increased 3.4% from 2000 to 2001. Projected 2002 exploitable biomass is about 204,000 mt, spawning biomass 193,000 mt, increases of 3.5 and 1.7% from the estimated values for 2001. **Alaska sablefish abundance now appears to be low and slowly increasing.** The slow increase confirms the projection from last year's assessment that abundance will increase slowly due to the above average 1997 year class; the size of the increase depends on the actual strength of the above-average 1997 year class and another year class that likely is above average, 1998. Spawning biomass is projected to increase to 35% of unfished spawning biomass ($B_{35\%}$) in 2002, having been as low as 33% of unfished spawning biomass during 1998 to 2000.

The 1977, 1980 and 1981 strong year classes appear to be exceptional year classes associated with the regime shift of 1976-1977. Subsequent year classes are weaker, but may be "normal" for the changed oceanographic state following the regime shift. A major change in the productivity of the stock appears to have occurred following these exceptional year classes.

Estimates of recruitment strength during the 1960's are uncertain because they depend on length rather than age data and because the abundance index is the fishery catch rate, which may be a biased measure of abundance. Late 1970's abundance may be overestimated; predicted mean weight is greater than observed mean weight, implying that predictions of how many fish survived the heavy fishing during the 1970's is overestimated. The observed population during the late 1970's appears to consist of more young fish than was predicted.

The age of 50% selection by the longline survey is about 4 years (Figure 9.11). The age of 50% selection is about 1 year later for the IFQ longline fishery, about the same for short open-access seasons ("derby" fishery), and about 1.5 years earlier for the trawl fishery. Selectivity is asymptotic for the longline survey and fishery and dome-shaped for the trawl fishery. Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishermen were pushed to fish shallower water that young fish inhabit (Sigler and Lunsford 2001). Young fish are more vulnerable and older fish are less vulnerable to the trawl fishery (see following figure [only 1996 data shown for brevity]) because trawling often occurs on the continental shelf and < 300 m water of the continental slope that young sablefish inhabit.



Catch rate data are available from 1990-2000. Data for the 2001 is incomplete. Catchability was separately estimated for the "derby" (through 1994) and IFQ (1995 and later) fisheries. On average fishery catchability is 1.8 times greater during the IFQ fishery, the same as estimated in an independent analysis of the effects of individual quotas on catching efficiency in the fishery (Sigler and Lunsford 2001). Like the selectivity effect, lower catching efficiency during the "derby" fishery likely occurred due to crowding of the fishing grounds, so that fishermen were pushed to fish areas where sablefish densities were less. Fishermen also fished the same area repeatedly, with associated decreases in catch rates due to "fishing down" the area.

A value of 0.104 was estimated for natural mortality in this year's assessment, similar to the value of 0.098 estimated in last year's assessment and the assumed value of 0.10 used in previous assessments.

Fishery catch rates often are biased estimates of relative abundance (e.g. Crecco and Overholtz 1990). We examined possible biases in US fishery catch rate data; see section 9.4.2. The assessment results shown in this section used both survey and fishery catch rates as measures of sablefish relative abundance. Because of the potential bias of sablefish fishery catch rates, we tested the effect of the sablefish fishery catch rates. Both Japan and US fishery catch rate data are used in the assessment, but we only tested the effect of US fishery catch rate data because there was no alternative abundance index during most years of the Japanese longline fishery, unlike the US fishery, which overlaps longline surveys. We found that US fishery catch rates have little effect on spawning biomass estimates. Their inclusion in the assessment model changed spawning biomass estimates from -0.3 to +0.6% for 1990-2000, the years of US fishery catch rate data.

9.7.2 Comparison to last year's model

The scale and trend of estimated spawning biomass, exploitable biomass, and recruitment are similar between the November 2000 and 2001 assessments, except for slightly increased estimated abundance (Figure 9.12). For example, 2002 spawning biomass estimated in the 2000 assessment is 6.6% greater than that estimated for the 2001 assessment.

9.8 Projections and harvest alternatives

9.8.1 Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2002 spawning biomass estimate, are shown in Table 9.10. Reference biomass values were computed for recruitment equal to average recruitment from the 1977-97 year classes. Projected 2002 spawning biomass is 35% of unfished spawning biomass and 88% of $B_{40\%}$. A downward adjustment to the reference fishing mortality rates is required to set the maximum Acceptable Biological Catch under Tier 3b.

Reference point values for fishing mortality increased from last year's assessment. For example, $F_{40\%}$ = 0.120 for last year's assessment and 0.133 for this year's assessment. The reference fishing mortalities increased because the estimate of natural mortality increased from 0.098 for last year's assessment to 0.106 for this year's assessment. This amount of variation in the estimated value of natural mortality is not unusual. The estimated value was 0.102 for the year before last's assessment. The estimate will continue to vary in future assessments as data is collected and added to the population model each year. The increased values of M and $F_{40\%}$ in part caused the maximum permissible fishing level to increase markedly between last year's and this year's assessment, from 16,900 mt to 21,300 mt (section 9.8.6).

9.8.2 Maximum sustainable yield

A spawner-recruit relationship has not been determined for sablefish, thus estimates of maximum sustainable yield are unavailable.

9.8.3 Population projections

Projected 2002 exploitable biomass is about 204,000 mt for Aleutian Islands, eastern Bering Sea, Gulf of Alaska combined, spawning (male and female) biomass 193,000 mt. Spawning biomass currently equals 35% of the unfished value. Future stock conditions depends on future average recruitment and fishing mortality (Figure 9.13). If catch is about 17,000 mt, then abundance is projected to increase through 2003, then decrease if future average recruitment equals 1982-1997 average recruitment. With the same catch and future average recruitment equal to 1977-1997 average recruitment, then abundance is projected to generally increase through 2006. The latter recruitment scenario is more optimistic because it includes the exceptional 1977-1981 year classes. Spawning biomass is projected to remain above 35% of the unfished value only if future recruitment equals the more optimistic recruitment level or if fishing mortality is substantially reduced. Projected abundance for 5-year average fishing mortality are similar to projected abundance for catch of 17,000 mt. Projected abundance for maximum permissible fishing mortality are substantially lower; spawning biomass is projected to decrease even for the more optimistic recruitment level. Abundance generally will increase in 2001 and later if fishing mortality is half maximum permissible or zero.

We also projected yields based on recruitment estimates from the whole time series of 1957+, in addition to the abundance and yield projections described in the previous paragraph for 1977+ and 1982+; abundance and yield projections for 1957+ are similar to 1977+ because average recruitment for both time intervals is similar, about 22 million 2-year old sablefish per year, compared to 16 million for 1982+.

Spawning biomass, fishing mortality, and yield also are tabulated for the seven standard projection scenarios (Table 9.11).

Status determination

Alaska sablefish are not overfished nor are they approaching an overfished condition (Table 9.11).

9.8.4 Bayesian analysis

The data provides information about the values of *M* and *q*. Their estimates are well-defined by the available data. Most of the probability lies between *M* of 0.07 and 0.15 and *q* of 9.2 and 12.2 (Figure 9.14). The probability changes smoothly and is well-mapped by the chosen values for the *q-M* grid. It is probably best to use the estimates, because they are well-defined by the data, and not develop priors for *M* and *q*.

We tested adding informative priors. Adding more informative priors narrowed the posterior, with the amount of narrowing depended on the variance assumed for the prior. Using biologists' opinion of the value of natural mortality is one method for developing an informative prior distribution. However these opinions would be based on years of interpreting results from age-structured models. Therefore adding an opinion-based prior to the age-structured model is not independent from the data. Therefore we chose to use only non-informative prior distributions.

Another approach for adding more informative priors which does not depend on sablefish data alone is a meta-analysis based on the value of natural mortality for other species. This would only be appropriate if the analysis included long-lived species of the Scorpaeniformes (which includes sablefish and rockfish) or a meta-analysis that uses other life history relationships such as natural mortality and the growth parameter *k*. During development of the Bayes and decision analyses we considered using meta-analysis priors for natural mortality as well as stock-recruitment relationship "steepness" and may add these priors to future sablefish assessments.

9.8.5 Decision analysis

In the decision analysis, we address the question: Given future catch levels, what is the probability that spawning biomass will decrease in the future? The years 2002 and 2006 were compared. The spawning biomass most likely will be the same in 2002 and 2006 for annual catch of 17,300 mt, i.e. the catch where probability equals 0.5 that 2006 spawning biomass is less than 2002 spawning biomass (Figure 9.15a). The probability that this catch will reduce 2006 spawning biomass to less than 90% of 2002 spawning biomass is near zero.

The decision analysis described above examines the probability of a decreasing trend. We also examined the probability that future abundance falls below a reference value, $B_{35\%}$. Note that $B_{35\%}$ is recomputed for each *q-M* pair. The probability of falling below $B_{35\%}$ differs little between the two catch levels examined, 17,300 and 21,300 mt (Figure 9.15b). In general, the probability lines are flatter with respect to catch for the second analysis. This approach does not test for a trend like the first analysis. For example, 2006 spawning biomass may be less than 2002 spawning biomass, but remain greater than $B_{35\%}$ if 2002 spawning biomass is large enough. than the first analysis. We will continue to choose an ABC based on the probability of a decreasing trend since sablefish abundance is low.

9.8.6 Acceptable biological catch

We recommend choosing the 2002 ABC based on the abundance trend because sablefish abundance is low. The decision analysis presented in the previous section addresses this concern and was used to recommend the 2000 and 2001 ABCs. The decision analysis indicates that a yield of 17,300 mt most likely will keep spawning biomass the same and has near-zero probability of reducing 2006 spawning biomass to less than 90% of 2002 spawning biomass. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is much higher, 21,300 mt. In contrast to a yield of 17,300 mt, the $F_{40\%}$ yield has a high probability (>0.99, decision analysis) of decreasing 2006 abundance below 2002 abundance and a substantial probability (0.18) of decreasing 2006 abundance below 90% of 2002 abundance. We recommend against the $F_{40\%}$ yield because this yield is likely to decrease spawning biomass. **We recommend a 2002 ABC of 17,300 mt for the combined stock**, a yield likely to maintain spawning biomass, and a yield slightly higher than the 2001 ABC of 16,900 mt (2% increase).

A slight ABC increase from 2001 to 2002 is consistent with a sablefish abundance trend that appears low and slowly increasing. Exploitable and spawning biomass are projected to increase 4 and 2%, respectively, from 2001 to 2002. The survey abundance index increased 16% in numbers and 13% in weight from 2000 to 2001. These increases follow decreases from 1999 to 2000 in the survey abundance index of 10% in numbers and 8% in weight and in the fishery abundance index of 5% in weight, so that relative abundance in 2001 is slightly higher than in 1999 (Table 9.5).

The fishing mortality for a 2002 ABC of 17,300 mt is 0.093, similar to the 5-year average fishing mortality of 0.088. Thus the recommended ABC will maintain fishing mortality. In contrast, the maximum permissible fishing mortality for 2002 (ABC of 21,300 mt) is 0.115, 31% greater than the 5-year average. Such a large increase does not seem reasonable given that sablefish abundance is low.

The maximum permissible fishing level increased markedly since last year's assessment, from 16,900 mt to 21,300 mt, a 26% increase. This increase has three causes. First, the estimate of natural mortality increased from 0.098 for last year's assessment to 0.106 for this year's assessment, so that $F_{40\%}$ increased from 0.120 to 0.133, an 11% increase (section 9.8.1). Second, estimated abundance increased. For example, 2002 spawning biomass estimated in the 2000 assessment is 6.6% greater than that estimated for the 2001 assessment (section 9.7.2). Third, projected spawning biomass increased from 34% of the unfished value in last year's assessment to 35% of the unfished value in last year's assessment, which lessens the downward adjustment of $F_{40\%}$, from 83% to 87%.

9.8.7 Regional and area apportionment

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of interannual changes in the allocation. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of biomass distribution, while adapting to current information about biomass distribution. However mixing rates for sablefish are sufficiently high and fishing rates sufficiently low that moderate variations of the biomass based apportionment would not significantly change overall sablefish yield unless there are strong areal differences in recruitment, growth, and survival (Heifetz et al 1997). The 1993 TAC was apportioned using a 5 year running average with emphasis doubled for the current year survey abundance index in weight (relative population weight or RPW). Since 1995, the ABC was allocated using an exponential weighting of regional RPW's. This method of determining weighting values depends on the assumed ratio between measurement (survey variance) to process error (recruitment, natural mortality, and migration variability). If survey variability is 1/N-th of total variability, the weighting factor is reduced 1/N-th each previous year. The sablefish longline surveys are assumed fairly accurate relative to many other surveys and probably survey variability is no more than ½ of total variability. A $(1/2)^x$ weighting scheme reduced annual fluctuations in ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model, where *x* is the year index (J. Heifetz, Auke Bay Lab, pers. comm.). The weights are year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000.

Previously, the Council approved allocations of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an allocation based on survey and fishery data. We also used survey and fishery data to allocate the 2002 ABC.

The fishery and survey information were combined to allocate ABC using the following method. The RPW based on the fishery data were weighted with the same exponential weights used to weight the survey data (year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000). The fishery and survey data were combined by computing a weighted average of the survey and fishery estimates, with the weight inversely proportional to the variability of each data source. The variance for the fishery data is about twice that for the survey data, so the survey data was weighted twice as much as the fishery data.

This method of combining the fishery and survey data appears reasonable, but using equal exponential weights for the fishery and survey data is not consistent with the theory used to determine the exponential weights. Weighting the survey data twice as much as the fishery data when combining the data, as described above, fits the theory. However using the same exponential weights for the fishery and survey data does not.

Apportionments are based on survey and fishery information	**2001 ABC Apportion ment**	**2001 Survey RPW**	**2000 Fishery RPW**	**2002 ABC Apportion ment**	**2001 ABC**	**2002 ABC**	**change**
Total					16,900	**17,300**	2%
Bering Sea	9%	14%	11%	11%	1,560	**1,930**	24%
Aleutians	15%	15%	14%	15%	2,500	**2,550**	2%
Gulf of Alaska	76%	71%	75%	74%	12,840	**12,820**	0%
Western	16%	23%	12%	17%	2,010	**2,240**	11%
Central	42%	44%	39%	42%	5,410	**5,430**	0%
W. Yakutat	15%	10%	21%	14%	1,880	**1,770**	-6%
E. Yakutat / Southeast	28%	23%	28%	26%	3,540	**3,380**	-5%

The 2002 apportionment percentages generally match both the survey and fishery regional estimates of abundance for the Bering Sea, Aleutians, and Gulf of Alaska. For example for the Gulf of Alaska, the 2001 ABC percentage is 74%, the 2001 survey RPW is 71% and the 2000 fishery RPW is 75%. Within the Gulf of Alaska, the survey and fishery percentages are less consistent, with the survey indicating more fish in the Western and Central Gulf of Alaska and fewer fish in the eastern Gulf of Alaska than the fishery. This occurs because survey catch rates are higher than fishery catch rates in the Western and Central Gulf of Alaska, whereas survey and fishery catch rates are similar in the eastern Gulf of Alaska (section 9.4.2, figure).

Lower ABCs are recommended for the eastern Gulf of Alaska. Abundance has steadily decreased in the eastern Gulf of Alaska during the 1990s, as well as the central Gulf of Alaska, though more slow and variable. This abundance decrease and when it may reverse are discussed in section 9.4.5.

Regional estimates of age-4+ biomass are tabulated in Table 9.12.

9.8.8 Overfishing level

Applying an adjusted $F_{35\%}$ as prescribed for Over Fishing Level (OFL) in Tier 3b results in a value of 26,100 mt for the combined stock. The OFL is apportioned by region, Bering Sea (2,900 mt), Aleutian Islands (3,850 mt), and Gulf of Alaska (19,350 mt), by the same method as the ABC apportionment.

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Table 9.1.--Sablefish fork length (cm), weight (kg), and proportion mature by age and sex.

	Fork length (cm)		Weight (kg)		Fraction mature	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2	50	52	1.2	1.4	0.059	0.006
3	53	56	1.5	1.7	0.165	0.024
4	55	59	1.7	2.1	0.343	0.077
5	57	62	1.9	2.4	0.543	0.198
6	59	64	2.1	2.7	0.704	0.394
7	61	66	2.3	3.0	0.811	0.604
8	62	68	2.4	3.3	0.876	0.765
9	63	70	2.6	3.6	0.915	0.865
10	64	71	2.7	3.9	0.939	0.921
11	65	72	2.8	4.1	0.954	0.952
12	65	74	2.9	4.3	0.964	0.969
13	66	75	3.0	4.5	0.971	0.979
14	66	76	3.1	4.7	0.976	0.986
15	67	76	3.1	4.9	0.979	0.990
16	67	77	3.2	5.1	0.982	0.992
17	67	78	3.2	5.2	0.984	0.994
18	67	78	3.2	5.3	0.985	0.995
19	68	79	3.3	5.4	0.986	0.996
20	68	79	3.3	5.5	0.987	0.997
21	68	80	3.3	5.6	0.988	0.997
22	68	80	3.3	5.7	0.988	0.998
23	68	80	3.4	5.8	0.989	0.998
24	68	81	3.4	5.9	0.989	0.998
25	68	81	3.4	5.9	0.989	0.998
26	68	81	3.4	6.0	0.990	0.998
27	68	81	3.4	6.0	0.990	0.999
28	69	81	3.4	6.1	0.990	0.999
29	69	82	3.4	6.1	0.990	0.999
30	69	82	3.4	6.1	0.990	0.999

Table 9.2--Alaska sablefish catch (mt), 1956-2000. The values include landed catch and discard estimates. Discards were estimated for U.S. fisheries before 1993 by multiplying reported catch by 2.9% for fixed gear and 26.9% for trawl gear (1994-1997 averages) because discard estimates were unavailable.

		BY AREA								BY GEAR	
Year	GRAND TOTAL	Bering Sea	Aleutians	Western	Central	Eastern	West Yakutat	E. Yakutat/ Southeast	Un-known	Fixed	Trawl
1956	773	0	0	0	0	773			0	773	0
1957	2,059	0	0	0	0	2,059			0	2,059	0
1958	477	6	0	0	0	471			0	477	0
1959	910	289	0	0	0	621			0	910	0
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,433	668	2,080	739	11,971	9,975	4,619	5,356	0	22,912	2,521
1994	23,760	694	1,726	555	9,495	11,290	4,497	6,793	0	20,797	2,963
1995	20,954	990	1,333	1,747	7,673	9,211	3,866	5,345	0	18,342	2,612
1996	17,577	697	905	1,648	6,772	7,555	2,899	4,656	0	15,390	2,187
1997	14,922	728	929	1,374	6,237	5,653	1,928	3,725	0	13,287	1,635
1998	14,108	614	734	1,435	5,877	5,448	1,969	3,479	0	12,644	1,464
1999	13,575	677	671	1,487	5,873	4,867	1,709	3,158	0	11,590	1,985
2000	15,919	828	1,314	1,587	6,172	6,018	2,066	3,952	0	13,906	2,013

Table 9.3--Discarded catches of sablefish (amount [mt] and percent of total catch) by target fishery, gear (H&L=hook & line, TWL=trawl), and management area for 1994 to 2000.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (H&L)	1994	7	4	16	1	11	2	75	1	39	1	66	1
	1995	5	1	8	1	40	2	111	2	71	2	132	2
	1996	7	2	9	1	33	2	137	3	56	2	79	2
	1997	8	4	19	3	41	3	116	2	88	5	123	3
	1998	6	4	5	1	91	6	210	5	46	2	184	5
	1999	2	1	34	6	38	3	124	3	27	2	68	2
	2000	2	1	7	1	49	4	168	4	46	2	159	3
Greenland	1994	1	1	2	3	0	-	0	-	0	-	0	-
turbot (H&L)	1995	82	48	40	53	0	-	0	-	0	-	0	-
	1996	75	41	5	17	0	-	0	-	0	-	0	-
	1997	92	40	1	11	0	-	0	-	0	-	0	-
	1998	85	31	7	5	0	-	0	-	0	-	0	-
	1999	45	24	13	19	0	-	0	-	0	-	0	-
	2000	27	15	15	14	0	-	0	-	0	-	0	-
Pacific cod (H&L)	1994	7	15	1	2	1	23	0	-	0	-	0	-
	1995	15	37	2	18	2	96	4	11	0	-	0	-
	1996	15	64	13	19	0	-	0	-	0	-	0	-
	1997	15	71	5	16	8	75	114	89	0	-	0	-
	1998	9	63	4	31	0	-	5	46	0	2	0	-
	1999	9	61	2	12	0	-	1	6	0	-	0	-
	2000	54	79	3	15	0	23	34	81	0	-	1	100
All other (H&L)	1994	0	0	0	0	0	-	0	-	4	72	0	-
	1995	0	0	3	83	0	-	0	-	0	-	0	7
	1996	0	57	0	6	0	-	0	-	0	-	0	-
	1997	1	39	0	-	0	-	0	-	0	-	0	-
	1998	2	90	0	-	0	-	3	36	0	5	6	48
	1999	0	5	0	0	0	4	1	61	1	26	6	48
	2000	1	100	0	2	0	-	0	5	0	-	0	-
Total H&L	1994	14	5	19	1	11	3	75	1	44	1	66	1
	1995	102	16	52	5	42	3	115	2	71	2	132	2
	1996	98	19	27	4	33	2	137	3	56	2	79	2
	1997	117	24	25	3	49	4	230	5	88	5	123	3
	1998	101	22	16	3	91	6	218	5	46	2	190	5
	1999	57	15	48	7	38	3	126	3	28	2	74	2
	2000	83	20	26	3	49	4	213	4	52	2	240	4

Table 9.3 cont.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (TWL)	1994	13	28	0	-	0	-	10	15	0	-	0	-
	1995	0	-	1	10	0	-	62	61	0	-	0	-
	1996	0	1	0	-	0	-	1	2	2	3	0	-
	1997	0	-	0	-	0	-	0	-	0	-	0	-
	1998	0	-	0	-	0	-	0	-	0	-	0	-
	1999	0	-	0	-	0	-	0	-	0	-	0	-
	2000	0	-	0	-	0	2	0	-	0	-	0	-
Rockfish (TWL)	1994	1	-	9	12	1	1	54	8	28	13	0	-
	1995	0	-	1	4	2	4	167	21	57	25	0	-
	1996	0	5	0	2	0	-	208	19	28	13	0	-
	1997	0	-	1	5	0	5	159	19	5	13	0	-
	1998	0	-	0	1	0	-	67	9	0	-	0	-
	1999	0	-	0	-	1	1	250	30	2	1	0	-
	2000	0	-	0	-	1	2	155	18	1	1	0	-
Arrowtooth (TWL)	1994	0	-	0	-	0	-	20	42	0	-	0	-
	1995	0	-	0	-	0	-	286	75	0	-	0	-
	1996	0	-	0	-	1	36	133	76	0	-	0	-
	1997	0	-	0	-	0	-	24	47	0	-	0	-
	1998	5	21	0	-	13	62	62	96	0	-	0	-
	1999	6	13	0	-	32	78	53	81	0	-	0	-
	2000	4	5	0	-	60	48	115	64	0	-	0	-
Deepwater flatfish (TWL)	1994	0	-	0	-	0	-	180	40	12	26	47	73
	1995	0	-	0	-	0	-	76	41	7	22	0	-
	1996	0	-	0	-	0	-	66	39	6	23	0	-
	1997	0	-	0	-	0	-	117	47	3	49	93	59
	1998	0	-	0	-	0	-	71	35	1	29	0	-
	1999	0	-	0	-	0	-	130	65	33	61	0	-
	2000	0	-	0	-	0	-	3	13	0	4	0	-
Shallow water flatfish (TWL)	1994	0	-	0	-	0	-	9	8	0	-	0	-
	1995	0	-	0	-	0	-	18	33	0	-	0	-
	1996	0	-	0	-	0	-	7	23	0	-	0	-
	1997	0	-	0	-	0	-	11	32	0	-	0	-
	1998	0	-	0	-	0	-	32	84	0	-	0	-
	1999	0	-	0	-	0	-	0	-	0	-	0	-
	2000	0	-	0	-	0	-	34	67	2	100	0	-
Rex sole (TWL)	1994	0	-	0	-	0	-	137	30	0	-	0	-
	1995	0	-	0	-	0	-	36	16	6	94	0	-
	1996	0	-	0	-	0	-	32	24	42	-	0	-
	1997	0	-	0	-	0	3	5	13	16	77	0	-
	1998	0	-	0	-	3	34	6	11	0	-	0	-
	1999	0	-	0	-	32	64	18	24	0	-	0	-
	2000	0	-	0	-	40	58	82	62	0	-	0	-
Greenland turbot (TWL)	1994	35	12	10	18	0	-	0	-	0	-	0	-
	1995	7	3	16	22	0	-	0	-	0	-	0	-
	1996	3	6	0	-	0	-	0	-	0	-	0	-

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
	1997	0	1	0	-	0	-	0	-	0	-	0	-
	1998	1	1	0	-	0	-	0	-	0	-	0	-
	1999	6	5	0	-	0	-	0	-	0	-	0	-
	2000	0	-	0	-	0	-	0	-	0	-	0	-
All other (TWL)	1994	17	48	0	4	3	54	35	25	0	-	0	-
	1995	13	61	3	49	8	70	18	20	0	-	0	-
	1996	16	26	10	77	2	13	1	13	0	-	0	-
	1997	11	37	0	23	1	15	44	48	0	-	0	-
	1998	7	11	4	43	4	62	56	54	1	39	0	-
	1999	37	29	0	-	39	99	122	86	0	-	0	-
	2000	48	37	0	23	11	98	108	75	0	-	0	-
Total TWL	1994	66	17	18	12	4	4	445	23	40	15	47	63
	1995	20	7	20	19	10	13	663	36	70	26	0	-
	1996	19	14	10	41	3	11	448	27	77	22	0	-
	1997	11	20	1	6	2	8	360	28	23	35	93	55
	1998	12	9	4	21	20	44	294	24	2	3	0	-
	1999	48	17	0	-	103	59	572	43	35	18	0	-
	2000	54	19	0	-	112	45	496	36	3	4	0	-
Grand total	1994	80	12	38	2	15	3	520	6	83	2	112	2
	1995	122	13	72	7	53	3	777	10	141	4	132	2
	1996	117	18	36	5	35	2	585	9	133	5	79	2
	1997	128	23	26	3	51	4	589	9	111	6	216	6
	1998	114	19	20	3	111	8	512	9	48	2	190	5
	1999	109	16	49	7	141	9	703	12	63	4	74	2
	2000	138	19	26	3	161	10	709	11	55	3	240	4

Table 9.4.--Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data.

	LENGTH						AGE	
	Japanese fishery		U.S. fishery		Cooperative longline survey	Domestic longline survey	Cooperative longline survey	Domestic longline survey
Year	Trawl	Longline	Trawl	Longline				
1963		30,562						
1964	3,337	11,377						
1965	6,267	9,631						
1966	27,459	13,802						
1967	31,868	12,700						
1968	17,727							
1969	3,843							
1970	3,456							
1971	5,848	19,653						
1972	1,560	8,217						
1973	1,678	16,332						
1974		3,330						
1975								
1976		7,704						
1977		1,079						
1978		9,985						
1979		1,292			19,349			
1980		1,944			40,949			
1981					34,699		1,146	
1982					65,092			
1983					66,517		889	
1984					100,029			
1985					125,129		1,294	
1986					128,718			
1987					102,639		1,057	
1988					114,239			
1989					115,067		655	
1990			1,229	33,822	78,794	101,530		
1991			721	29,615	69,653	95,364	902	
1992			0	21,000	79,210	104,786		
1993			468	23,884	80,596	94,699	1,178	
1994			89	13,614	74,153	70,431		
1995			87	18,174		80,826		
1996			239	15,213		72,247		1,175
1997			0	20,311		82,783		1,211
1998			35	8,900		57,773		1,183
1999			1,268	26,662		79,451		1,188
2000			472	29,240		62,513		1,236

Table 9.5.--Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. One or two indices of population abundance were computed: catch per effort in numbers weighted by respective strata areas to produce a relative population number (RPN) and catch per effort measured in weight multiplied by strata areas, to produce a relative population weight (RPW). Indices were extrapolated for unsampled survey areas: Aleutian Islands 1979, 1995, 1997, 1999; Bering Sea 1979-1981, 1995, 1996, 1998.

	RPN		**RPW**			
Year	**Cooperative longline survey**	**Domestic longline survey**	**Japanese longline fishery**	**Cooperative longline survey**	**Domestic longline survey**	**U.S. fishery**
1964			1,452			
1965			1,806			
1966			2,462			
1967			2,855			
1968			2,336			
1969			2,443			
1970			2,912			
1971			2,401			
1972			2,247			
1973			2,318			
1974			2,295			
1975			1,953			
1976			1,780			
1977			1,511			
1978			942			
1979	413		809	1,075		
1980	388		1,040	968		
1981	460		1,343	1,153		
1982	613			1,572		
1983	621			1,632		
1984	685			1,822		
1985	903			2,569		
1986	838			2,456		
1987	667			2,068		
1988	707			2,088		
1989	661			2,178		
1990	450	649		1,454	2,141	1,201
1991	386	593		1,321	2,071	1,066
1992	402	511		1,390	1,758	908
1993	395	563		1,318	1,894	904
1994	366	489		1,288	1,882	822
1995		501			1,803	1,243
1996		520			2,017	1,201
1997		491			1,764	1,341
1998		466			1,662	1,130
1999		511			1,740	1,209
2000		461			1,597	na

Table 9.6.--Average CPUE (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. Note: standard error not available when vessel sample size equals one.

Observer Fishery Data

	Bering Sea						Aleutian Islands				
Year	CPUE	SE	CV	# Sets	Vessels	Year	CPUE	SE	CV	# Sets	Vessels
1990	0.37	0.07	0.10	715	39	1990	0.51	0.20	0.20	182	7
1991	0.26	0.11	0.21	55	15	1991	0.45	0.06	0.07	547	17

Year	CPUE	SE	CV	# Sets	Vessels
1992	0.15	0.06	0.20	13	6
1993	0.13	0.08	0.30	29	4
1994	0.32	0.36	0.57	8	4
1995	0.38	0.11	0.15	60	16
1996	0.44	0.16	0.19	51	17
1997	0.30	0.11	0.19	30	10
1998	0.24	0.10	0.21	38	10
1999	0.17	0.05	0.16	49	17
2000	0.22	0.06	0.14	36	12

Year	CPUE	SE	CV	# Sets	Vessels
1992	0.39	0.07	0.09	369	11
1993	0.28	0.07	0.13	705	10
1994	0.29	0.08	0.14	405	22
1995	0.29	0.06	0.10	345	15
1996	0.23	0.04	0.08	251	18
1997	0.37	0.10	0.14	157	11
1998	0.23	0.06	0.13	94	10
1999	0.31	0.08	0.14	369	16
2000	0.28	0.07	0.12	377	16

Western Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.54	0.23	0.21	214	10
1991	0.43	0.11	0.12	284	9
1992	0.32	0.04	0.07	522	25
1993	0.29	0.05	0.09	214	6
1994	0.29	0.07	0.12	78	5
1995	0.56	0.18	0.17	508	22
1996	0.53	0.09	0.09	302	22
1997	0.47	0.08	0.09	375	21
1998	0.46	0.05	0.05	337	15
1999	0.60	0.07	0.06	377	23
2000	0.50	0.10	0.10	233	16

Central Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.59	0.10	0.08	816	51
1991	0.54	0.13	0.12	666	11
1992	0.56	0.09	0.08	764	41
1993	0.76	0.51	0.34	1191	7
1994	0.53	0.13	0.12	474	25
1995	0.80	0.09	0.06	749	37
1996	0.85	0.10	0.06	599	59
1997	0.92	0.10	0.06	567	51
1998	0.85	0.09	0.05	508	39
1999	0.89	0.13	0.07	338	38
2000	0.84	0.11	0.06	419	50

West Yakutat

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.65	0.16	0.13	135	19
1991	0.63	0.16	0.13	300	9
1992	0.54	0.21	0.20	314	20
1993	0.57	0.12	0.11	515	5
1994	0.55	0.29	0.27	124	8
1995	0.98	0.18	0.09	267	23
1996	0.90	0.13	0.07	284	33
1997	1.21	0.18	0.08	177	29
1998	1.11	0.16	0.07	226	32
1999	1.32	0.28	0.11	117	21
2000	1.39	0.22	0.08	207	33

East Yakutat / Southeast

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.60	0.60	0.51	39	3
1991	0.69	0.27	0.20	57	5
1992	0.62	0.27	0.22	47	4
1993	0.80	0.03	0.02	40	2
1994	0.32			5	1
1995	1.21	0.32	0.14	164	18
1996	1.10	0.19	0.09	185	30
1997	1.26	0.24	0.10	157	38
1998	1.21	0.18	0.08	260	34
1999	1.09	0.17	0.08	135	18
2000	0.99	0.27	0.14	91	17

Required Logbook Fishery Data

Bering Sea

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.52	0.14	0.14	523	52
2000	0.19	0.09	0.23	530	28

Aleutian Islands

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.36	0.17	0.24	475	17
2000	0.19	0.06	0.16	1008	28

Western Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.56	0.13	0.12	394	23
2000	0.60	0.10	0.09	667	44

Central Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.84	0.15	0.09	807	83
2000	0.79	0.08	0.05	1253	127

West Yakutat

Year	CPUE	SE	CV	# Sets	Vessels
1999	1.11	0.23	0.10	210	36
2000	1.07	0.10	0.05	463	59

East Yakutat / Southeast

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.93	0.15	0.08	169	16
2000	0.98	0.17	0.09	325	40

Table 9.7.–Sablefish abundance (relative population weight, RPW) from annual sablefish longline surveys (domestic longline survey only) and number of stations where sperm whale (SW) and killer whale (KW) depredation of sablefish catches occurred. Some stations were not sampled all years, indicated by “na”. Recording of sperm whale depredation began with the 1998 survey.

Year	Bering			Aleutians			Western		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	na	na	na	na	na	na	244,164	na	0
1991	na	na	na	na	na	na	203,357	na	1
1992	na	na	na	na	na	na	94,874	na	1
1993	na	na	na	na	na	na	234,169	na	2
1994	na	na	na	na	na	na	176,820	na	0
1995	na	na	na	na	na	na	198,247	na	0
1996	na	na	na	186,270	na	1	213,126	na	0
1997	160,300	na	3	na	na	na	182,189	na	0
1998	na	na	na	271,323	0	1	203,590	0	0
1999	136,313	0	7	na	na	na	192,191	0	0
2000	na	na	na	260,665	0	1	242,707	0	1
2001	248,019	0	4	na	na	na	294,277	0	0

Year	Central			West Yakutat			East Yakutat / Southeast		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	684,738	na	0	268,334	na	0	393,964	na	0
1991	641,693	na	0	287,103	na	0	532,242	na	0
1992	568,474	na	0	316,770	na	0	475,528	na	0
1993	639,161	na	0	304,701	na	0	447,362	na	0
1994	603,940	na	0	275,281	na	0	434,840	na	0
1995	595,903	na	0	245,075	na	0	388,858	na	0
1996	783,763	na	0	248,847	na	0	390,696	na	0
1997	683,294	na	0	216,415	na	0	358,229	na	0
1998	519,781	0	0	178,783	4	0	349,350	0	0
1999	608,225	3	0	183,129	5	0	334,516	4	0
2000	506,368	0	0	158,411	2	0	303,716	2	0
2001	561,168	3	0	129,620	0	0	290,747	2	0

Table 9.8a.–Ages that above average year classes became abundant by region (see figure on following page). "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska.

Year class	Western	Central	Eastern
1977	na	4	4
1980-81	4-5	7-8	9-10
1984	4-5	8-9	8-9
1990	4-6	7	7
1995	4	>5	>5
1997	>3	>3	>3

Table 9.8b–Predicted years that the above average 1995 and 1997 year classes will become abundant by region. "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska.

Year class	Western	Central	Eastern
1995	already present	2002 to 2004	2002 to 2005
1997	2001 to 2003	2004 to 2006	2004 to 2007

Table 9.9.--Sablefish age 4+ biomass, exploitable biomass, spawning biomass, and catch (thousands mt), and number (millions) at age 2 by year. Projected values assume catch of 17,300 mt and recruitment based on average for 1982-1997 year classes.

Year	Age 4+ biomass	Exploitable biomass	Spawning biomass	Number (millions) at age 2	Catch	Catch / Age 4+ biomass
1960	292	252	251	5.2	3.1	0.011
1961	280	250	247	19.9	16.1	0.057
1962	256	234	232	129.3	26.4	0.103
1963	246	206	216	4.9	16.9	0.069
1964	424	204	234	3.9	7.3	0.017
1965	428	248	285	10.4	8.7	0.020
1966	422	333	337	87.9	15.6	0.037
1967	408	368	362	5.2	19.2	0.047
1968	504	358	359	6.5	31.0	0.062
1969	470	356	367	66.7	36.8	0.078
1970	422	363	363	17.4	37.8	0.090
1971	469	353	356	9.0	43.5	0.093
1972	428	324	329	9.1	53.0	0.124
1973	380	316	314	2.1	36.9	0.097
1974	338	300	293	1.5	34.6	0.102
1975	287	266	257	2.4	29.9	0.104
1976	240	230	220	32.1	31.7	0.132
1977	196	189	185	2.0	21.4	0.109
1978	213	162	164	3.3	10.4	0.049
1979	197	153	160	85.7	11.9	0.060
1980	183	158	165	33.4	10.4	0.057
1981	302	164	183	5.6	12.6	0.042
1982	343	182	212	62.0	12.0	0.035
1983	341	240	257	42.5	11.8	0.035
1984	422	320	300	3.2	14.1	0.033
1985	465	386	326	11.2	14.5	0.031
1986	448	424	353	29.4	28.9	0.065
1987	418	406	356	11.8	35.2	0.084
1988	407	374	334	9.7	38.4	0.094
1989	363	341	299	3.5	34.8	0.096
1990	326	311	276	26.6	32.1	0.099
1991	282	279	252	4.0	27.0	0.096
1992	278	253	225	30.3	24.9	0.090
1993	249	242	212	13.4	25.4	0.102
1994	260	232	200	11.8	23.8	0.092
1995	249	203	195	6.2	20.9	0.084
1996	239	203	191	20.8	17.6	0.074
1997	222	199	188	17.9	14.9	0.067
1998	230	192	184	6.3	14.1	0.061
1999	238	192	184	43.5	13.6	0.057
2000	223	193	184	5.2	15.9	0.071
2001	269	198	190	7.7	15.9	0.059
2002	255	205	194		17.3	0.068
2003	242	214	197		17.3	0.071
2004	240	208	196		17.3	0.072
2005	236	197	187		17.3	0.073
2006	235	194	184		17.3	0.074

Table 9.10--Alaska sablefish harvest information.

M	0.106
Age at 50% selection for survey	4.3
Age at 50% selection for "derby" fishery	4.3
Age at 50% selection for IFQ fishery	5.1
Equilibrium unfished spawning biomass	552
Reference point spawning biomass, $B_{40\%}$	221
Reference point spawning biomass, $B_{35\%}$	193
2002 exploitable biomass	204
2002 spawning biomass	193
Ratio 2002 : unfished spawning biomass	0.35
HARVEST ALTERNATIVES	
Maximum permissible fishing level	
$F_{40\%}$	0.133
2002 $F_{40\%\ adj}$	0.115
2002 $F_{40\%\ adj}$ Yield	21.3
Overfishing level	
$F_{35\%}$	0.165
2002 $F_{35\%\ adj}$	0.143
2002 $F_{35\%\ adj}$ Yield	26.1
Authors' recommendation	
2002 F	0.093
2002 ABC	17.3

Table 9.11--Alaska sablefish spawning biomass, fishing mortality, and yield for seven harvest scenarios. The reference spawning biomass used to determine if the population is overfished, $B_{35\%}$, is 193 thousand mt, which sablefish are projected to reach in 2002, so Alaska sablefish are not classified as overfished. Projections are based on the 1977 to 1997 year classes.

Year	Maximum permissible F	Fraction maximum F	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass							
2001	190	190	190	190	190	190	190
2002	193	193	193	193	193	193	194
2003	194	197	203	198	213	189	199
2004	191	198	209	200	230	183	202
2005	185	193	209	196	239	175	196
2006	190	200	218	203	259	179	199
2007	196	207	229	211	278	184	199
2008	203	216	241	221	300	190	202
2009	208	222	249	227	317	193	203
2010	215	231	262	238	341	200	206
2011	219	236	270	244	359	202	207
2012	222	240	277	250	375	204	208
2013	224	243	283	254	390	206	208
2014	225	245	288	258	404	206	207
Fishing mortality							
2001	0.088	0.088	0.088	0.088	0.088	0.088	0.088
2002	0.115	0.093	0.058	0.088	0.000	0.143	0.116
2003	0.116	0.095	0.061	0.088	0.000	0.141	0.119
2004	0.114	0.095	0.062	0.088	0.000	0.136	0.148
2005	0.109	0.092	0.061	0.088	0.000	0.129	0.142
2006	0.110	0.093	0.062	0.088	0.000	0.130	0.141
2007	0.112	0.094	0.062	0.088	0.000	0.131	0.139
2008	0.114	0.095	0.063	0.088	0.000	0.134	0.140
2009	0.114	0.096	0.063	0.088	0.000	0.135	0.139
2010	0.116	0.098	0.064	0.088	0.000	0.138	0.141
2011	0.118	0.098	0.064	0.088	0.000	0.139	0.141
2012	0.118	0.099	0.065	0.088	0.000	0.140	0.142
2013	0.119	0.100	0.065	0.088	0.000	0.141	0.141
2014	0.119	0.100	0.065	0.088	0.000	0.141	0.141
Yield							
2001	15.9	15.9	15.9	15.9	15.9	15.9	15.9
2002	21.3	17.3	10.9	16.4	0.0	26.1	21.5
2003	21.9	18.5	12.3	17.2	0.0	25.7	22.8
2004	20.7	18.0	12.7	16.8	0.0	23.4	28.1
2005	19.3	17.1	12.4	16.5	0.0	21.4	26.6
2006	20.3	18.1	13.3	17.2	0.0	22.4	27.0
2007	21.4	19.1	14.1	17.9	0.0	23.6	27.1
2008	22.7	20.3	15.0	18.7	0.0	25.0	27.7
2009	23.5	21.1	15.6	19.4	0.0	25.8	27.8
2010	24.7	22.2	16.5	20.2	0.0	27.1	28.6
2011	25.4	22.9	17.1	20.8	0.0	27.7	28.6
2012	25.9	23.4	17.7	21.3	0.0	28.1	28.8
2013	26.3	23.9	18.1	21.7	0.0	28.4	28.8
2014	26.4	24.1	18.4	21.9	0.0	28.5	28.8

Table 9.12.--Regional estimates of sablefish age-4+ biomass. Age 4+ biomass was estimated by year and region by applying only survey-based weights, similar to the method used to allocate the ABC (except that the ABC allocation also used fishery data).

Year	Bering Sea	Aleutian Islands	Gulf of Alaska	Alaska
1979	35	38	124	197
1980	32	36	115	183
1981	51	72	180	302
1982	59	77	207	343
1983	58	69	214	341
1984	75	86	261	422
1985	85	101	279	465
1986	86	95	267	448
1987	83	83	252	418
1988	59	86	261	407
1989	45	68	250	363
1990	45	64	217	326
1991	38	47	198	282
1992	26	42	209	278
1993	21	34	193	249
1994	15	35	210	260
1995	18	34	198	249
1996	18	33	188	239
1997	19	25	178	222
1998	20	24	186	230
1999	21	32	185	238
2000	18	33	171	223
2001	22	42	206	269
2002	28	39	188	255

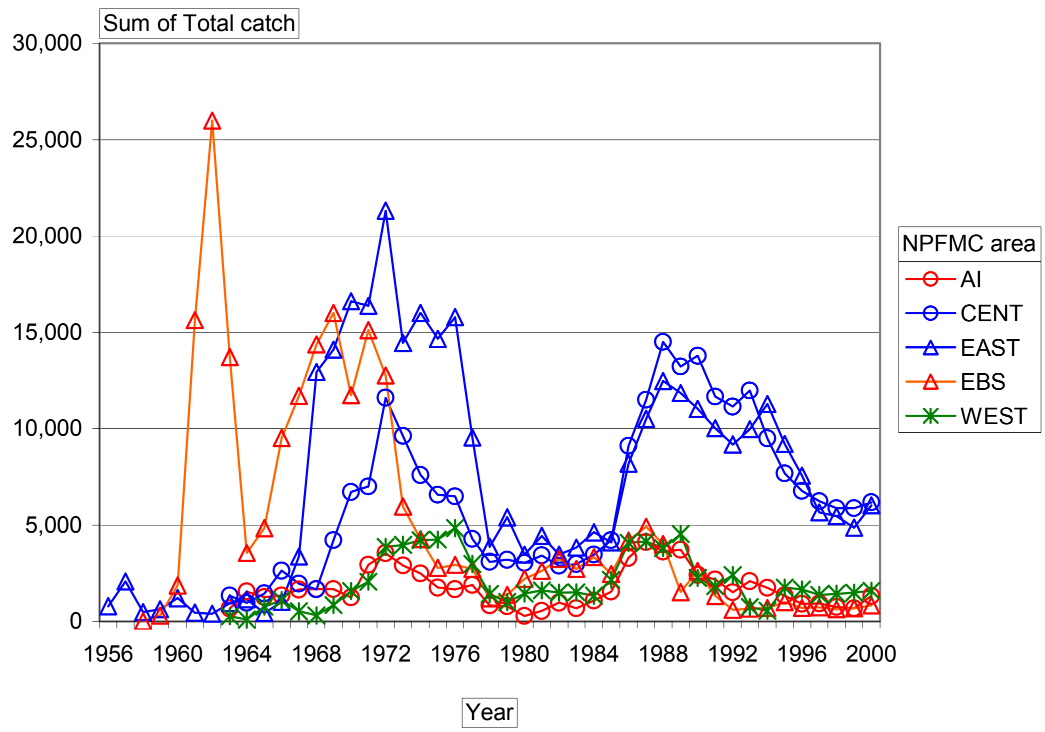

Figure 9.1–Sablefish fishery total reported catch (mt) by area and year.

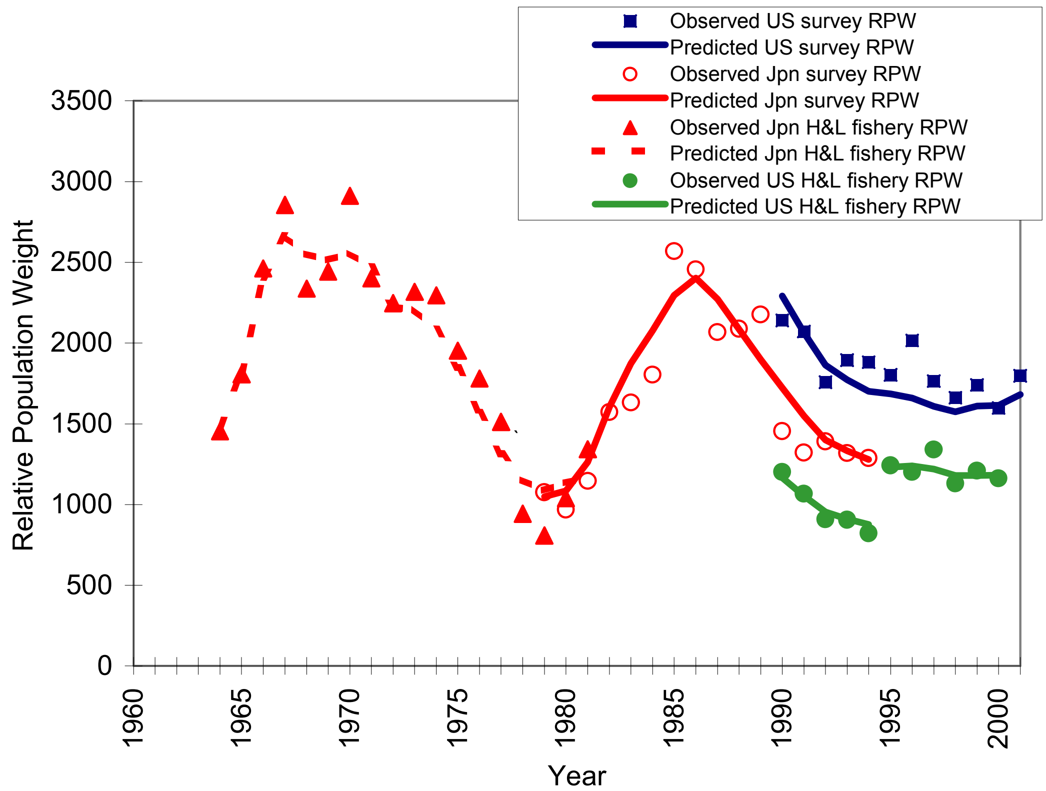

Figure 9.2.--Observed and predicted sablefish relative population weight versus year.

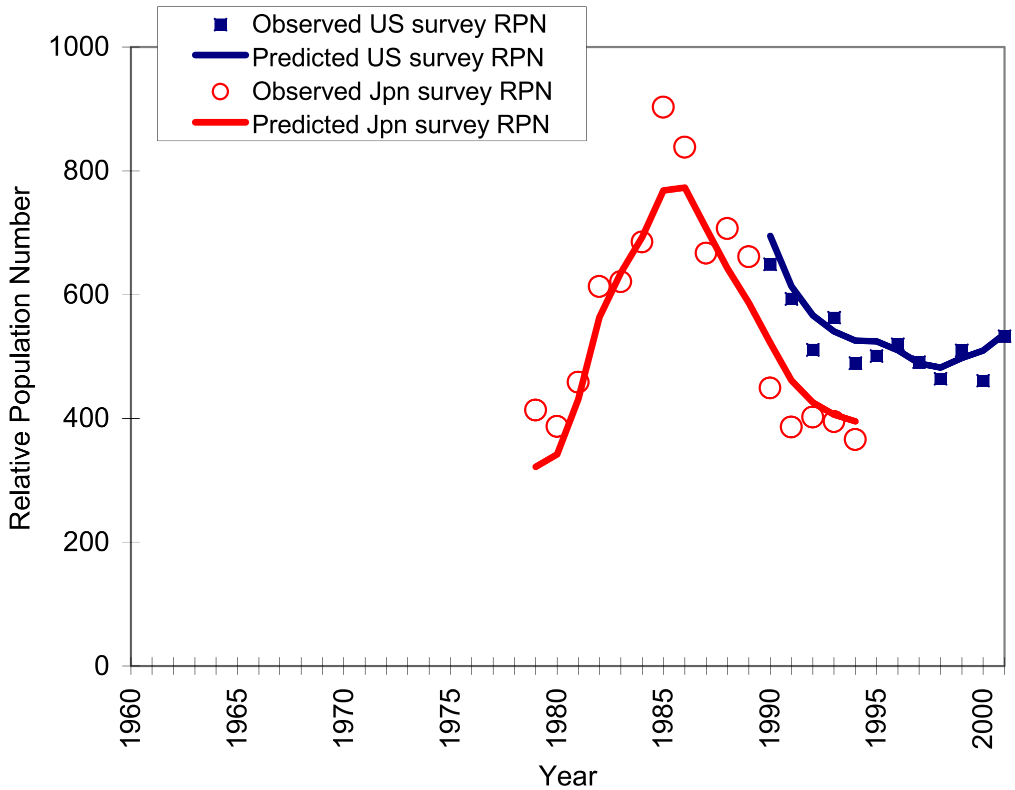

Figure 9.3.--Observed and predicted sablefish relative population number versus year.

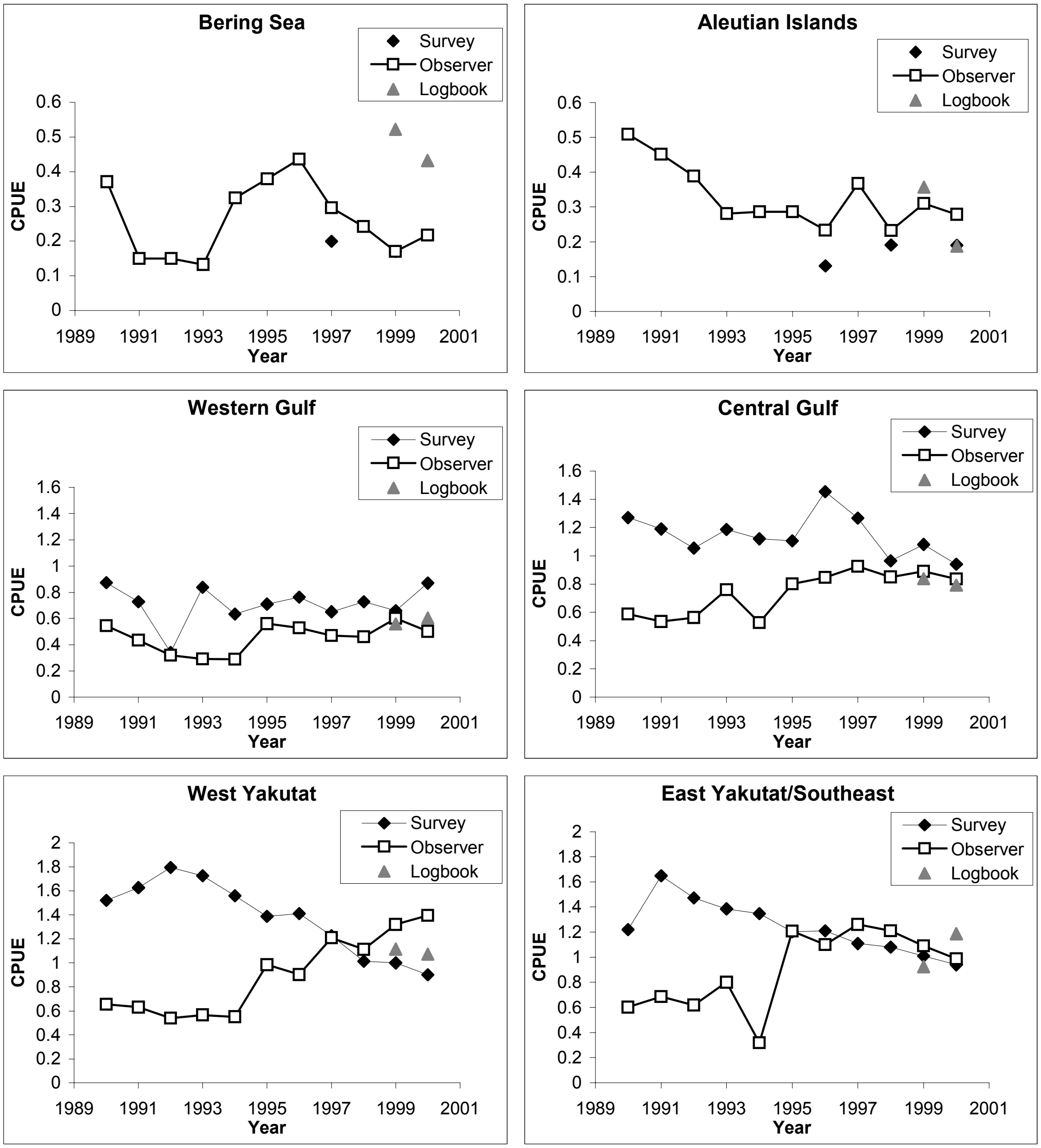

Figure 9.4.–Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data, 1990-2000.

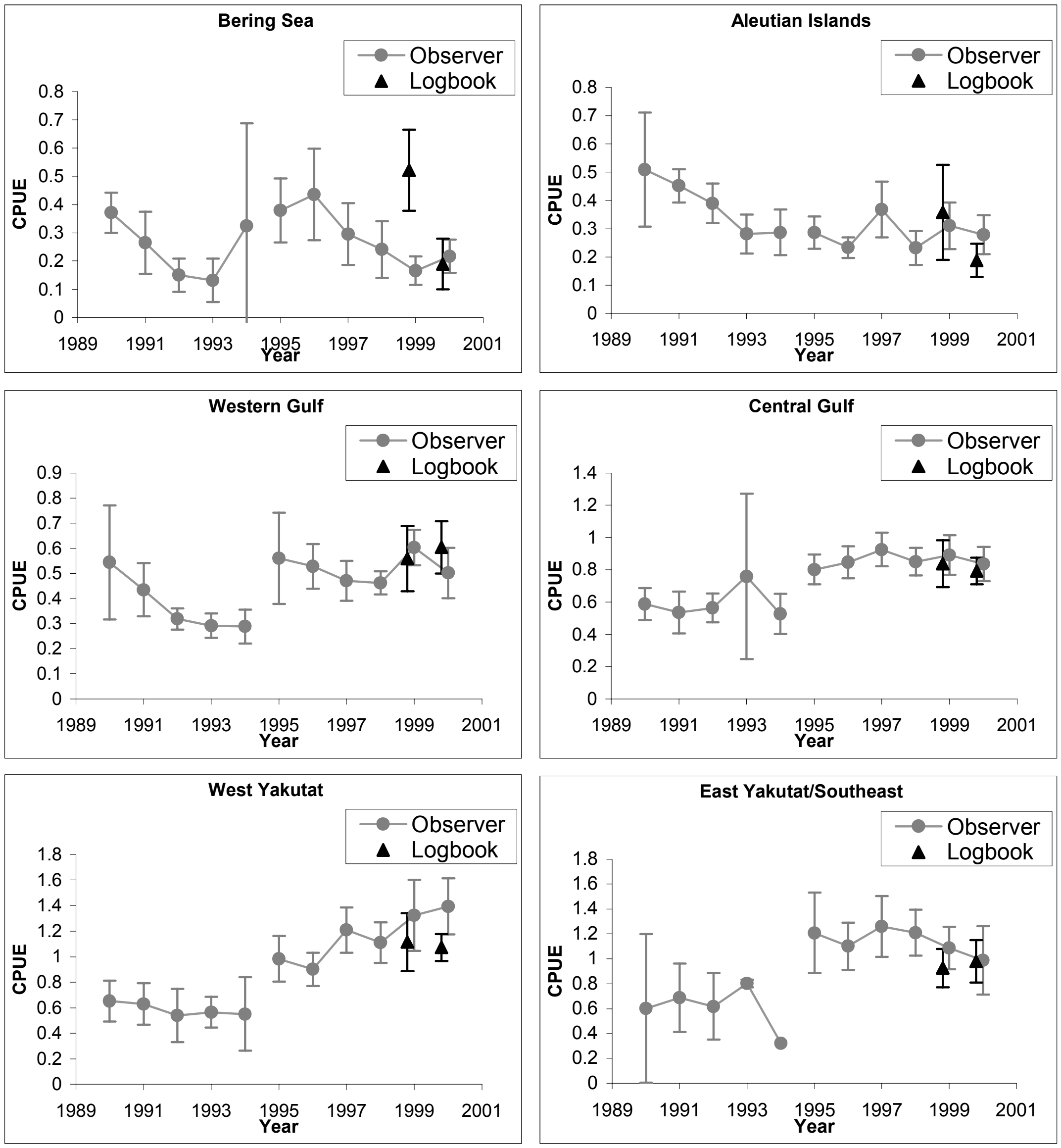

Figure 9.5.–Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source, 1990-2000.

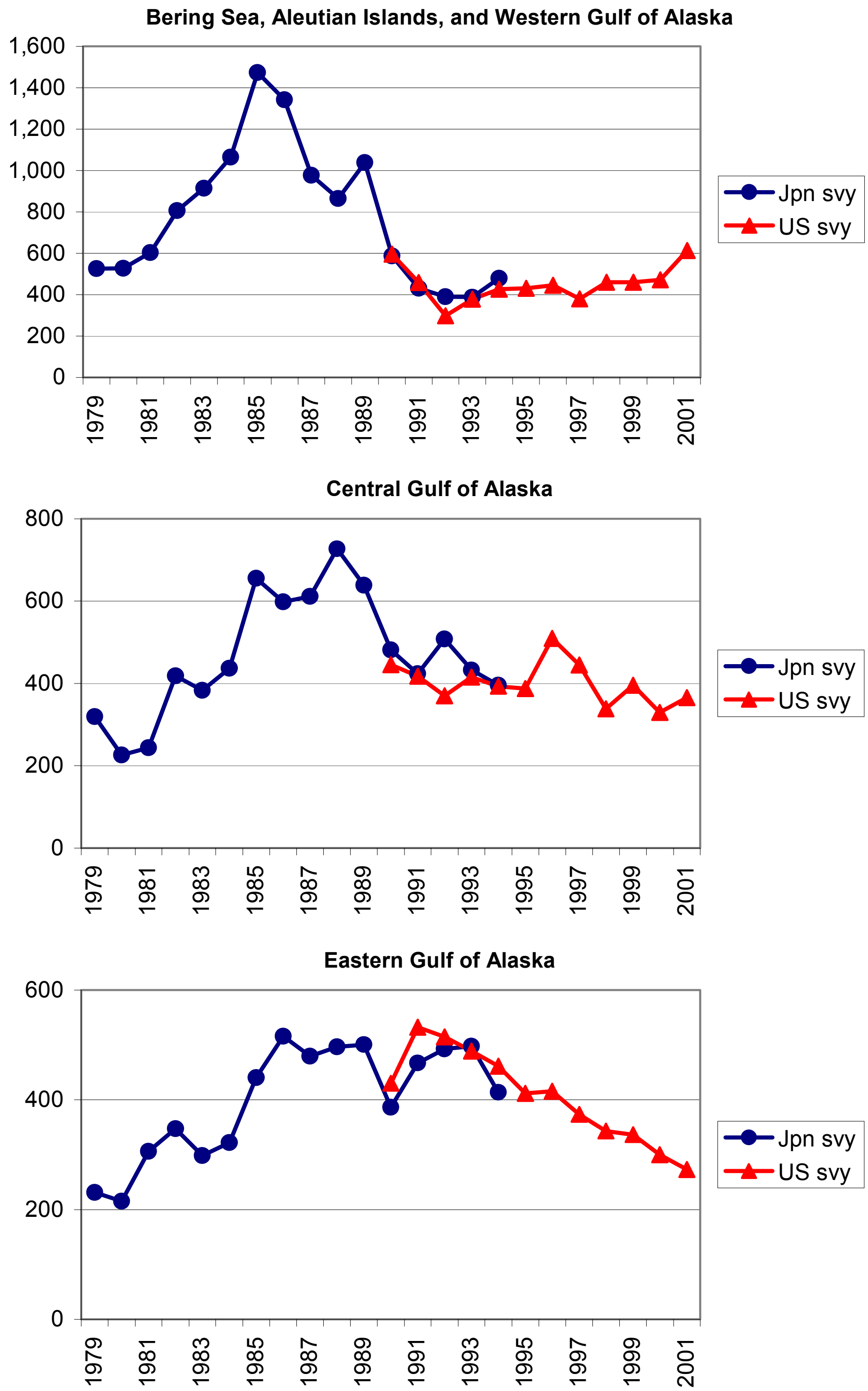

Figure 9.6.--Plot of relative abundance in weight by region and survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear.

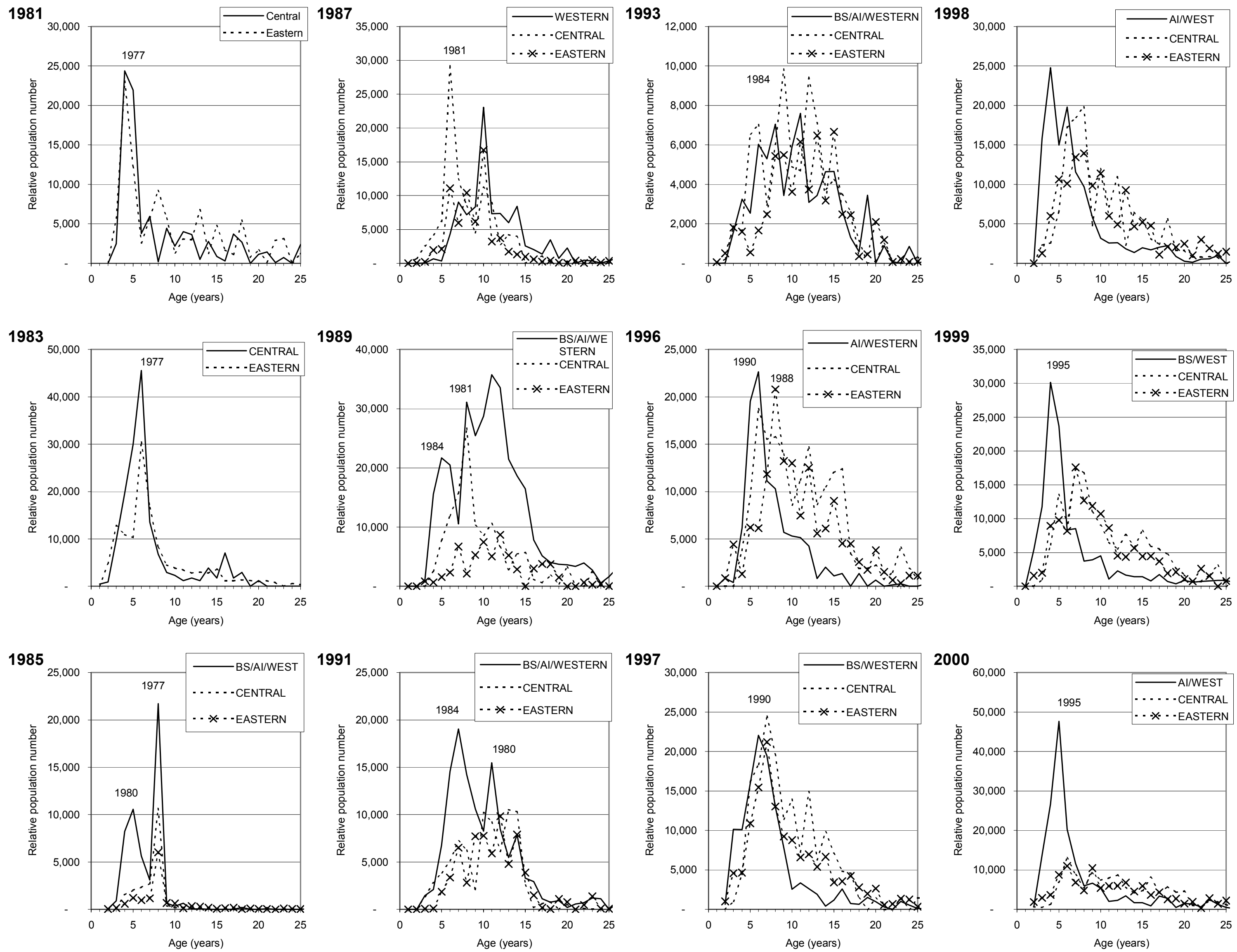

Figure 9.7.---Plot of relative abundance in number by age and region. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined in the age plots.

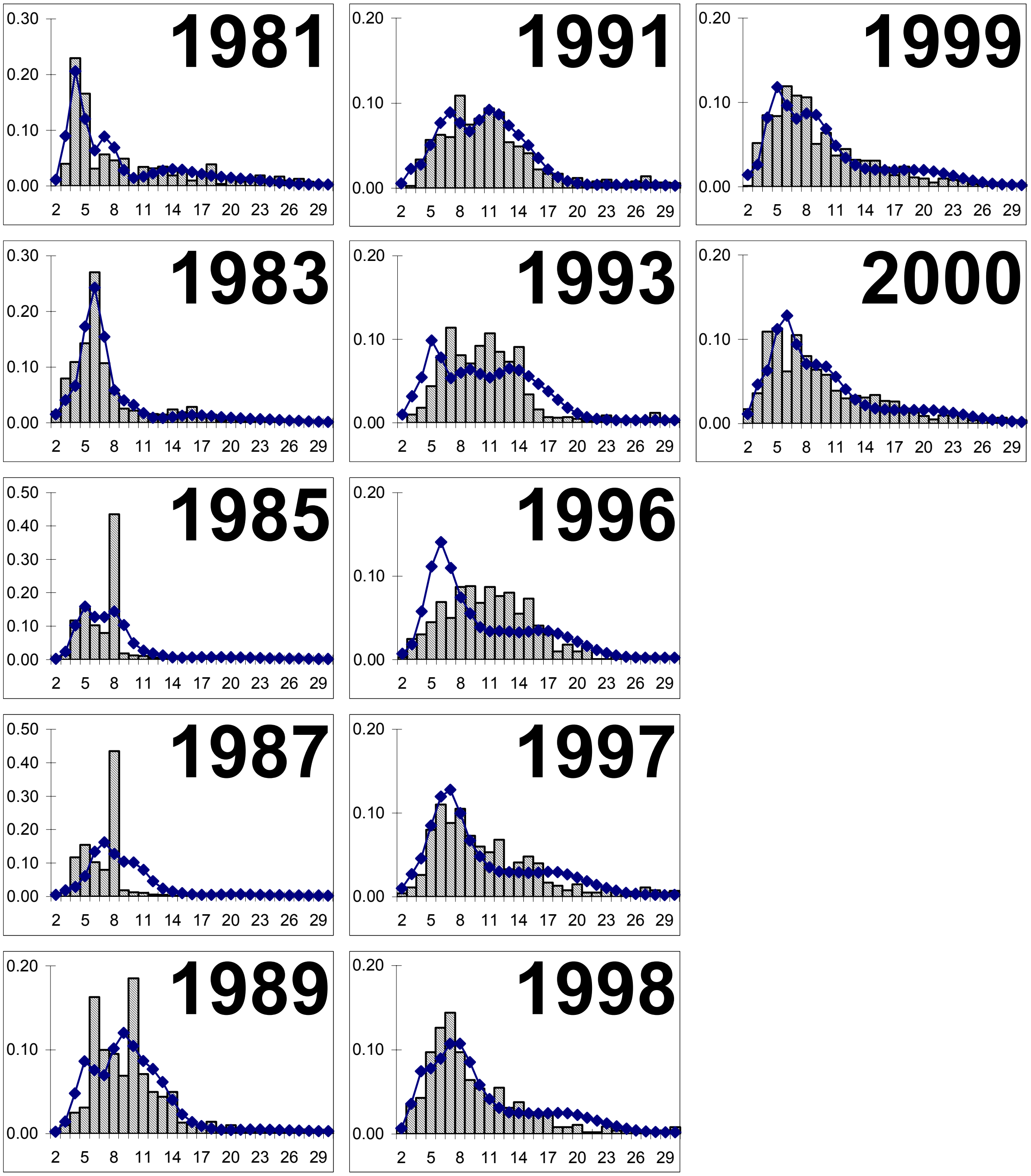

Figure 9.8 Observed (bar) and predicted (line) sablefish survey age frequency by age group and year.

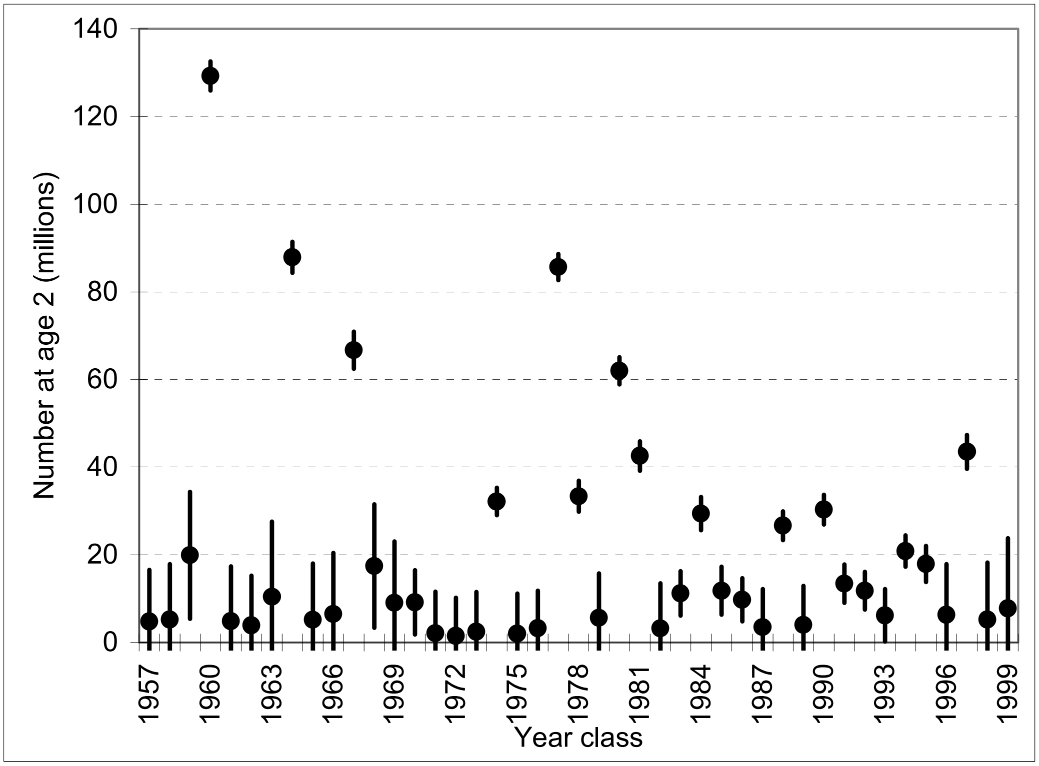

Figure 9.9.--Model estimates of the number of age-2 sablefish (millions) +/- 2 standard errors by year class. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated.

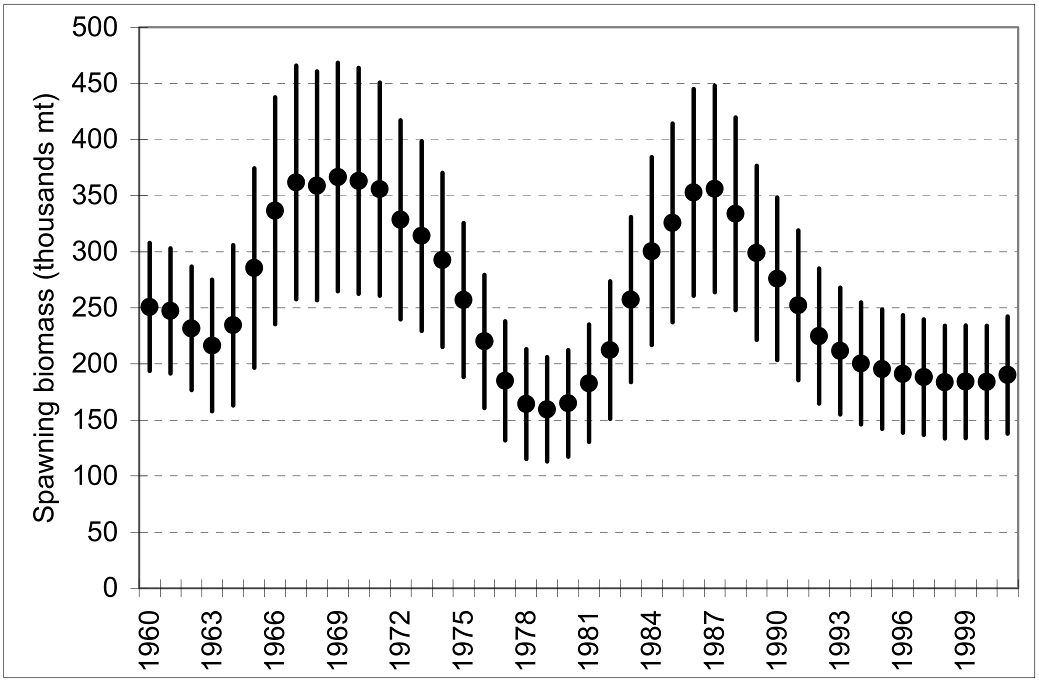

Figure 9.10.--Model estimates of male and female spawning biomass (thousands mt) +/- 2 standard errors by year. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated..

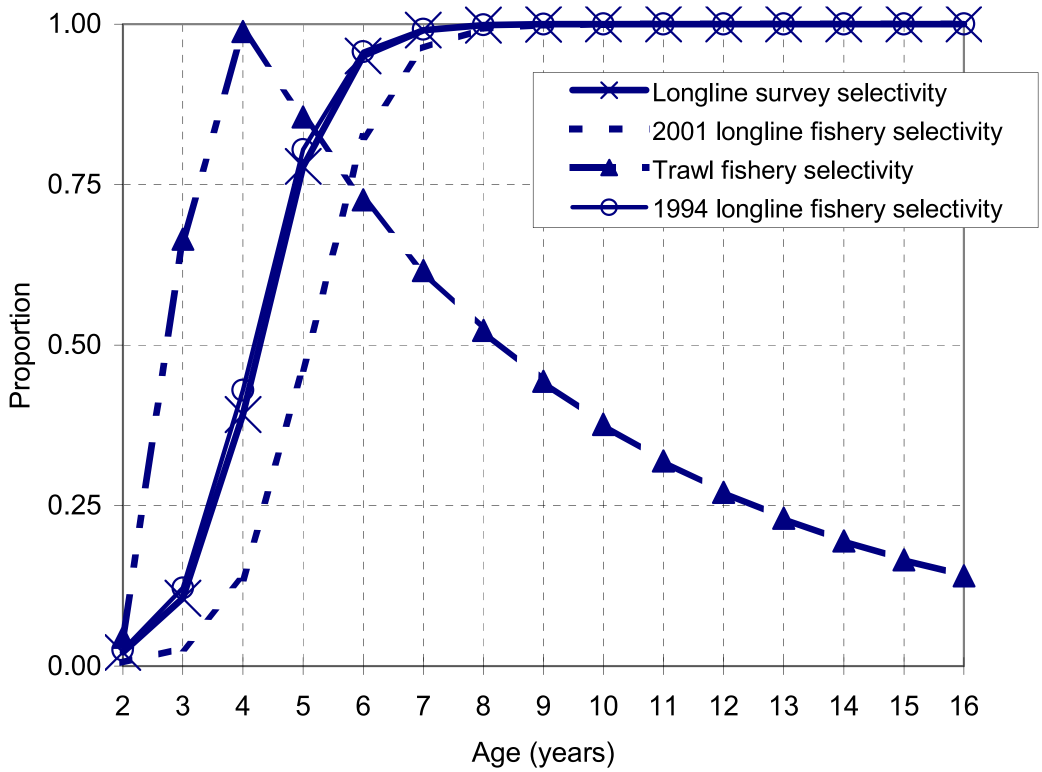

Figure 9.11 Sablefish survey, longline fishery, and trawl fishery selectivity functions. We chose to display the 1994 and 2001 longline selectivity functions because they are representative of the selectivity functions for the short open-access seasons ("derby" fishery) and IFQ seasons respectively.

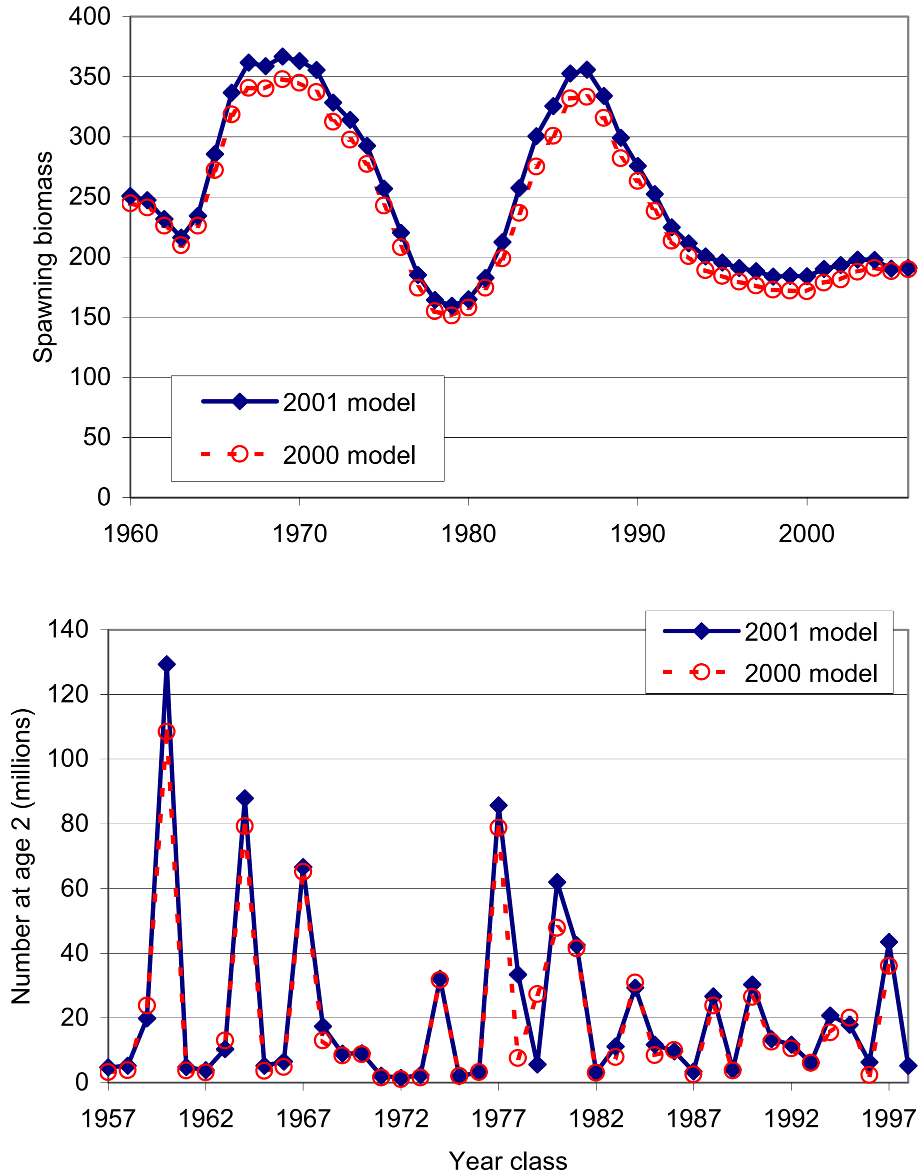

Figure 9.12 Estimated and projected sablefish spawning biomass (thousands mt) versus year and estimated recruitment (number at age 2, millions) for the 2000 and 2001 assessments.

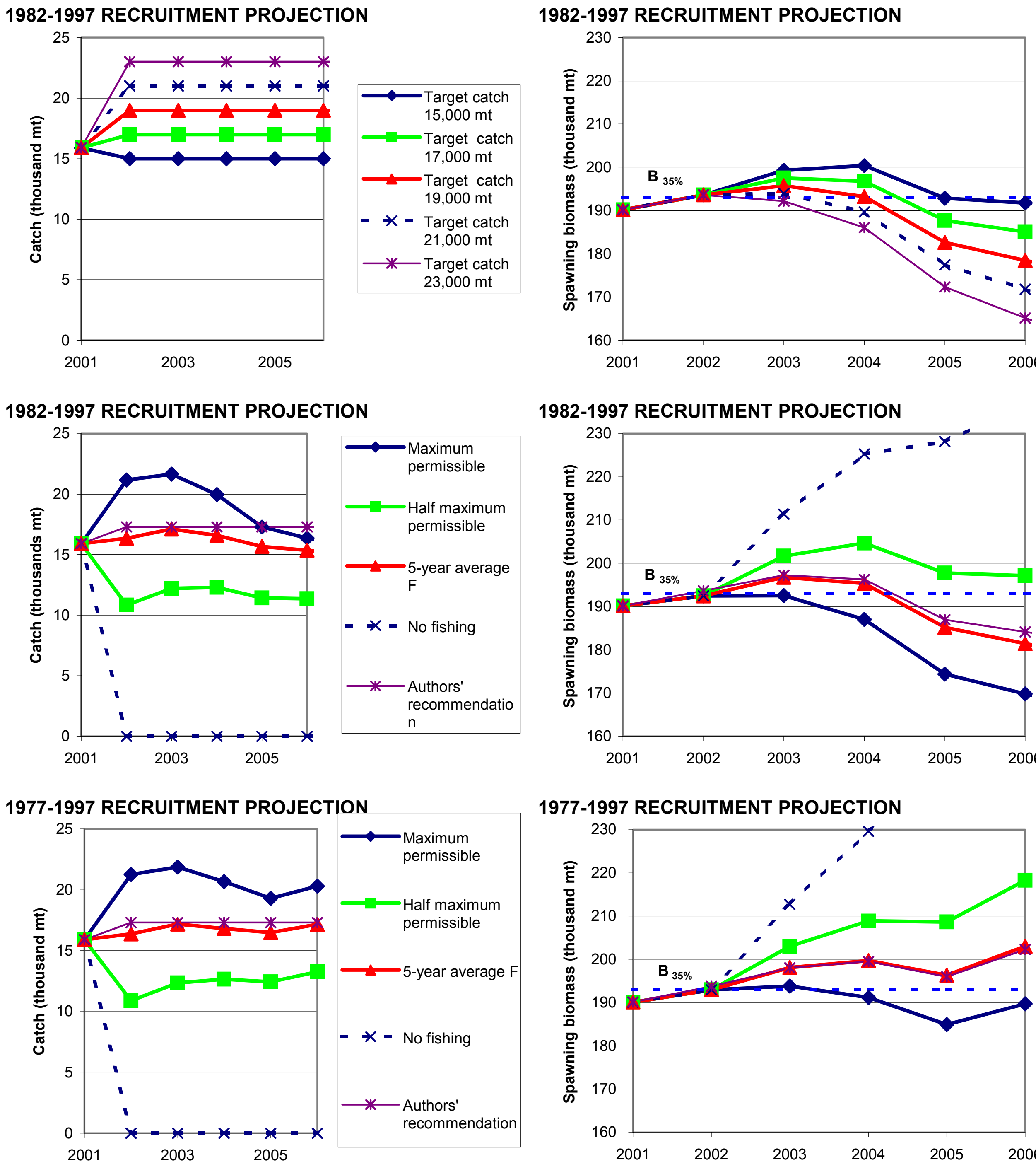

Figure 9.13--Sablefish spawning biomass and catch (thousands mt) for two recruitment scenarios and several harvest alternatives. Recruitment is projected using average recruitment for the 1982-1997 year classes or for the 1977-1997 year classes, which includes the exceptional 1977-1981 year classes. The harvest alternatives are described in section 9.5.1, *Standard set of population projections* and *Decision Analysis*. The authors' recommended ABC is 17,300 mt.

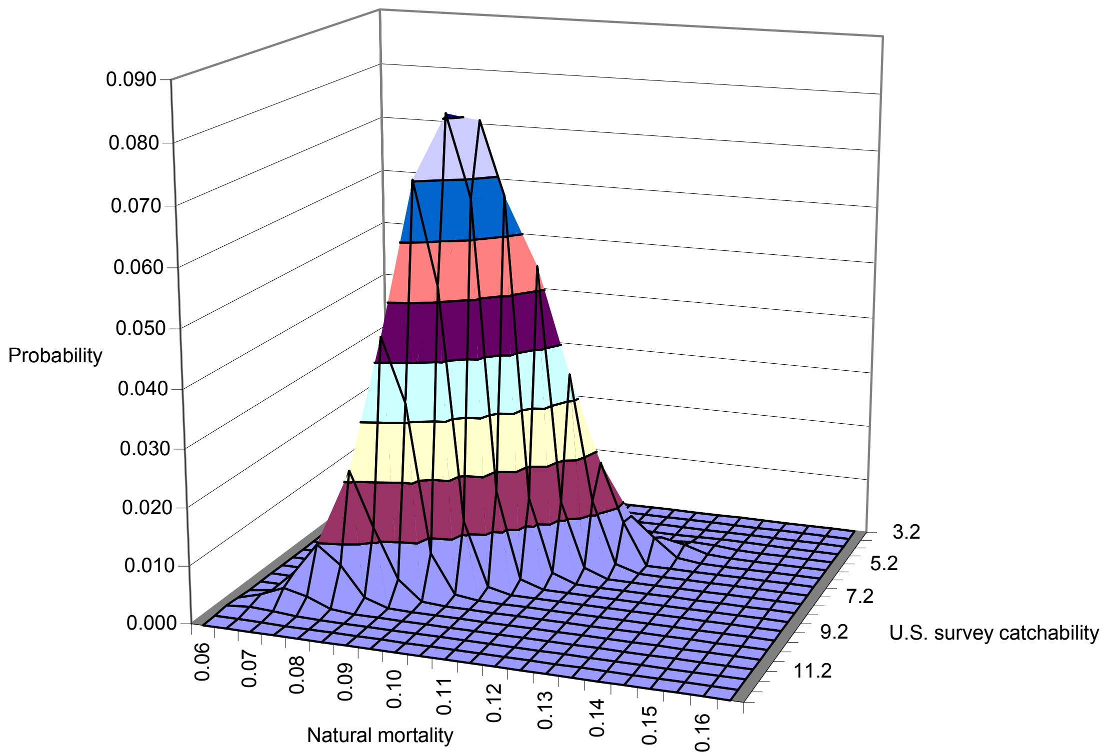

Figure 9.14.--Posterior probability versus catchability and natural mortality.

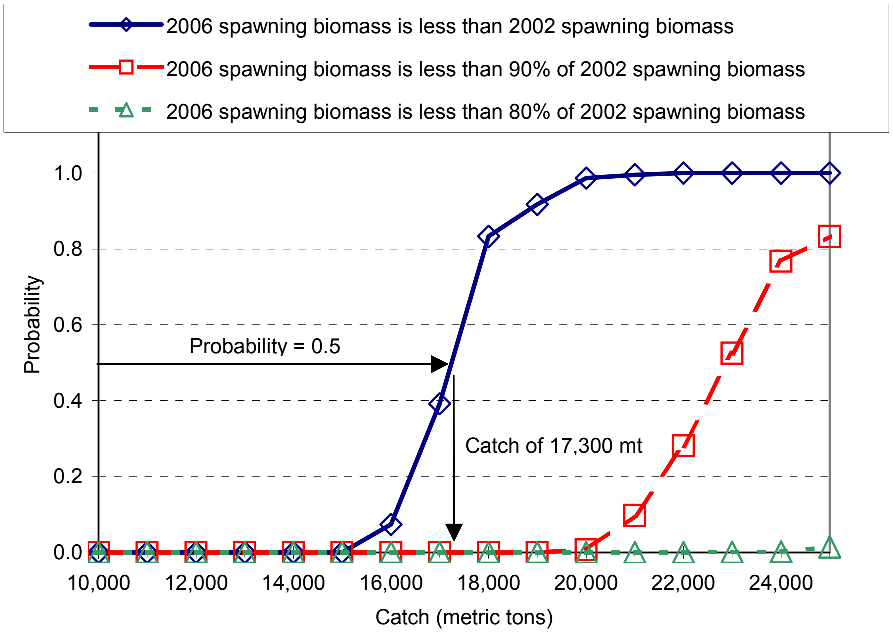

Figure 9.15a.–Probability that a given catch will reduce 2006 spawning biomass to less than 100%, 90%, and 80% of 2002 spawning biomass.

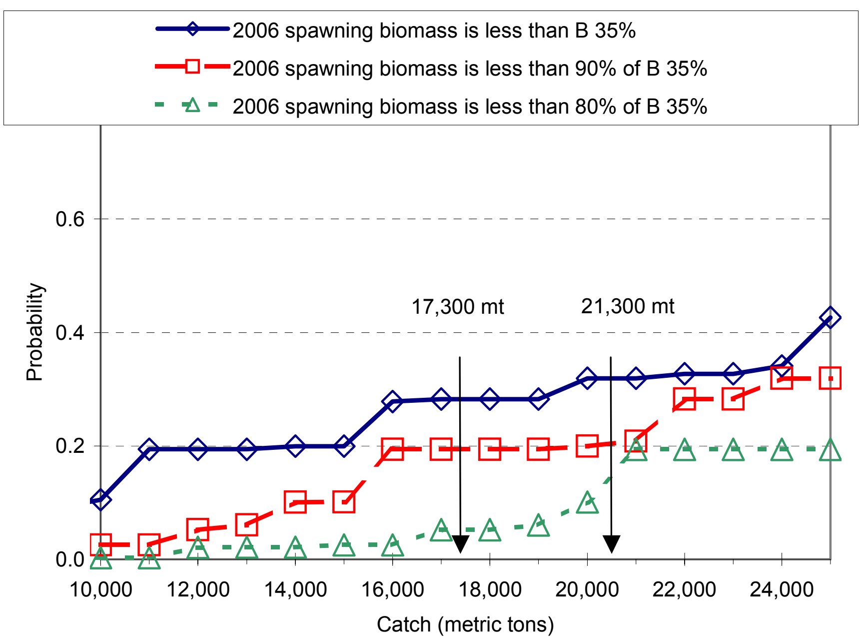

Figure 9.15b.--Probability that a given catch will reduce 2006 spawning biomass to less than 100%, 90%, and 80% of $B_{35\%}$.

Appendix A.--The equations listed below were used to compile the fishery and survey data used in the assessment. Some notes about the data are: The strata for U.S. fisheries data are Bering, Aleutians, Western, Central, West Yakutat, East Yakutat / Southeast, but are coarser for the Japanese fisheries: Bering Sea and Aleutians combined and Western, Central, West Yakutat, East Yakutat / Southeast combined, i.e. Gulf of Alaska.

Fishery data

For all years, let

w_k = weight at length k,

A_m = Areal size of strata.

For each year, let

Y_m = catch in weight for strata m,

Y_{mn} = catch in weight for strata m and set n,

E_{mn} = effort in number of hooks for strata m and set n,

f_{km} = proportion for length k and strata m,

then

$U_m \equiv \frac{\sum_n Y_{mn}/E_{mn}}{N}$ = Catch per hook for strata m,

$RPW_m \equiv U_m A_m$ = Relative population weight for strata m,

$\overline{w}_m \equiv \sum_k f_{km} w_k$ = mean weight

$c_m \equiv y_m / \overline{w}_m$ = catch in number

$f_k \equiv \sum_m f_{km} c_m / \sum_m c_m$ = proportion at length for Alaska

Length frequencies by statistical area were used to "randomize" the earlier age collections and compute an age frequency representative of the area's surveyed population (Kimura 1977). The age frequencies by area were weighted by the area RPN, then summed across area to obtain an RPN weighted age frequency for Alaska.

Appendix B.--The equations listed below were used to represent the sablefish population in Alaska.

Let $i = 1, \ldots y$ be the year index, and $j = 1, \ldots a$ be the age index. Let

c_i = the observed catch in numbers,
μ_i = the exploitation rate for fully vulnerable ages (i.e., ages for which $s_j = 1$),
s_j = the selectivity for age j fish such that the assumption of "separability" holds, i.e.,
$\mu_{ij} = \mu_i s_j$ = the exploitation fraction of age j fish during year i,
N_{ij} = the total number at age,
$N_{ij}^f = s_j N_{ij}$ = the fishable number at age, and
$N_i^f = \sum_{j=1}^{a} N_{ij}^f$ = the fishable number.

$U_{ij} = F_{ij} / (M + F_{ij})\,(1 - \exp(-M - F_{ij}))$ is the exploitation rate on age j fish in year i, assuming an instantaneous natural mortality rate of M. It follows that

$$N_{i+1,j+1} = N_{ij} e^{-M-F_{ij}}$$
and predicted catch would be $\hat{c}_{ij} = U_{ij} N_{ij}$.

A function which can describe either asymptotic or dome-shaped selectivity is the "exponential-logistic" function (Thompson 1994):

$$s_j = \left(\frac{1}{1-\gamma} \right) \left(\frac{1-\gamma}{\gamma} \right)^{\gamma} \left(\frac{e^{\beta\gamma(A_{50}-j)}}{1+e^{\beta(A_{50}-j)}} \right)$$

This function's advantages are that it automatically scales maximum vulnerability to 1.0, reduces to an asymptotic function of age as γ approaches zero, and A_{50} and β have biological meaning when $\gamma = 0$: A_{50} is the age where 50% of the population is vulnerable and β is the slope of the function at A_{50}.

We allowed A_{50} to vary with season length,

$$A_{50}^{s} = A_{50} \frac{1}{1+e^{-\beta(s-m_{50})}}$$

where s is season length in months, and A_{50}, β, and m_{50} are estimated.

A predicted abundance index in numbers is

$$\hat{S}_i = \hat{q} \hat{N}_i^f$$
where q is survey catchability and quantities predicted with the model are denoted with "hats." A predicted abundance index in weight is computed by multiplying the predicted abundance index in numbers by the predicted mean weight of the available population.

An ageing error matrix based on known-age otoliths (Heifetz et al 1999) was used to account for ageing error. Known-age otoliths were obtained in the following manner. Age-1+ sablefish have been tagged and released in nearshore waters of southeast Alaska annually since 1985. Otoliths sometimes were collectd with recoveries. These known-age fish were read in a blind test, where the age reader did not know the true age. The assigned ages were used to compute how often the true age was assigned, and if they differed, by how much. For example, of true age 3 fish, 0.15 were assigned age 2, 0.61 age 3, 0.23 age 4, and 0.01 age 5. The resultant matrix was used in the population model to convert predicted true age to predicted reader age. The known-age ageing error matrix was not available for last year's assessment and instead, age data were aggregated over several ages {2, 3, 4, 5, 6, 7, 8, 9-10, 11-15, 16+}, as suggested by Deriso et al. (1989) if errors are present in age compositions.

An age-length transition matrix also was calculated from the survey results, where l_{jk} = the probability that a fish sampled of age class j will be of length class k. The predicted length distributions are

$$\hat{f}_{ik} = \sum_{j} \hat{p}_{ij} l_{jk}$$

The length data were aggregated into 2-cm length classes by sex: {40-41, 42-43, . . . 98-99 cm fork length}.

Parameters can be estimated by assuming the probability distributions of the sampled abundnace indices, age, and length data are known. Fournier and Archibald (1982) suggested multinomial errors for age data and log-normal errors for catch data. Log-normal errors were assumed for the abundance indices and multinomial errors for the age and length data. The log-likelihood incorporating the sablefish data is (not all data is shown for brevity)

$$L = \sum_{ij} m_i p_{ij} \log\frac{\hat{p}_{ij}}{p_{ij}} + \sum_{ik} n_i f_{ik} \log\frac{\hat{f}_{ik}}{f_{ik}} - \frac{1}{2\sigma^2}\sum_{i} (\log(S_i) - \log(\hat{q}\hat{N}_i^f))^2$$

where m_i and n_i are the number of ages and lengths sampled in year i and σ^2 is the variance of the observed abundance index. Maximum likelihood estimates for the parameters can be found by maximizing L. As noted by Kimura (1989, 1990), reliability in the estimation process is improved if the log-parameters rather than parameters on the original scale are estimated. This makes the parameters more similar in magnitude, and probably reduces parameter-effects non-linearity (Ratkowsky 1983).

Data weighting

The variances of the age data and the survey index were estimated independently of the population modeling (Kimura 1977, Sigler and Fujioka 1988) and were used to weight the likelihood components of the population model. The estimated c.v. for the survey index is 0.05 and for the age data is 0.6. The effective sample size assuming a multinomial distribution was computed from the variance of the age data. Variances of the age and length data were assumed equal.

Appendix C.--Sablefish longline survey - fishery interactions, 1995-2001

NMFS has requested the assistance of the fishing fleet to avoid the annual sablefish longline survey since the inception of sablefish IFQ management in 1995. We requested that fishermen stay at least five nautical miles away from each survey station for 7 days before and 3 days after the planned sampling date (3 days allowed for survey delays). Beginning in 1999, we also revised the longline survey schedule to avoid the July 1 rockfish trawl fishery opening as well as other short, but less intense fisheries.

History of interactions

Publicity, the revised longline survey schedule, and fishermen cooperation generally have been effective at reducing trawl fishery interactions. No interactions were reported in 2000 and only one in 2001.

Distribution of the survey schedule to all IFQ permit holders, radio announcements from the survey vessel, and the threat of a regulatory rolling closure have had intermittent success at reducing the annual number of longline fishery interactions. The number of fishing vessels has been about 10, except 1999 and 2001, when the numbers were 3 and 1. Fifty different longline vessels have interacted with the survey vessel since 1995, about 10% of the fleet.

LONGLINE SURVEY - FISHERY INTERACTIONS

	Longline		Trawl		Total	
Year	**Stations**	**Vessels**	**Stations**	**Vessels**	**Stations**	**Vessels**
1995	8	7	9	15	17	22
1996	11	18	15	17	26	35
1997	8	8	8	7	16	15
1998	10	9	0	0	10	9
1999	4	4	2	6	6	10
2000	10	10	0	0	10	10
2001	1	1	1	1	2	2

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions decreased in 1999 and 2001. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance.

Michael Sigler and Chris Lunsford, Alaska Fisheries Science Center 11 October 2001

Appendix D.--Research survey catches (kg) by survey type, 1977-2000.

Year	Echo integration trawl	Trawl	Japan US longline survey	Domestic longline survey	Total
1977		3,126			3,126
1978	23	14,302			14,325
1979		27,274	103,839		131,113
1980		69,738	114,055		183,793
1981	813	87,268	150,372		238,452
1982		107,898	239,696		347,595
1983	44	45,780	235,983		281,807
1984		127,432	284,431		411,864
1985		185,692	390,202		575,894
1986	80	123,419	395,851		519,350
1987		116,821	349,424		466,245
1988		14,570	389,382	302,670	706,622
1989		3,711	392,624	367,156	763,491
1990	94	25,835	272,274	366,236	664,439
1991		3,307	255,057	386,212	644,576
1992	168	10	281,380	392,607	674,165
1993	34	39,275	280,939	407,839	728,088
1994	65	852	270,793	395,443	667,153
1995				386,169	386,169
1996	0	12,686		426,479	439,165
1997	0	1,080		396,266	397,347
1998	5	25,528		310,564	336,096
1999	0	43,224		293,149	293,149
2000	0	2,316		271,654	271,654
2001	2	11,411		304,125	315,538